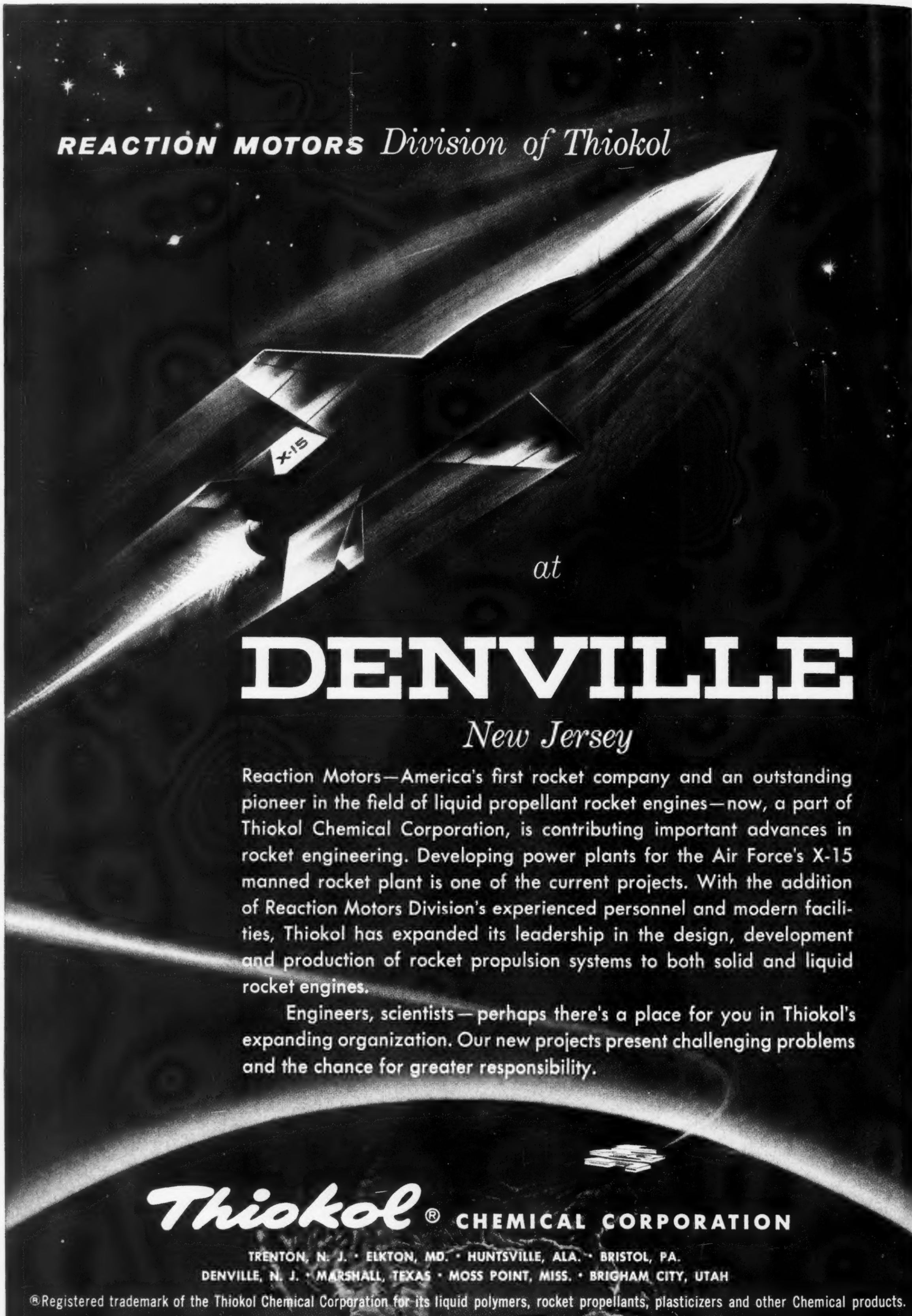
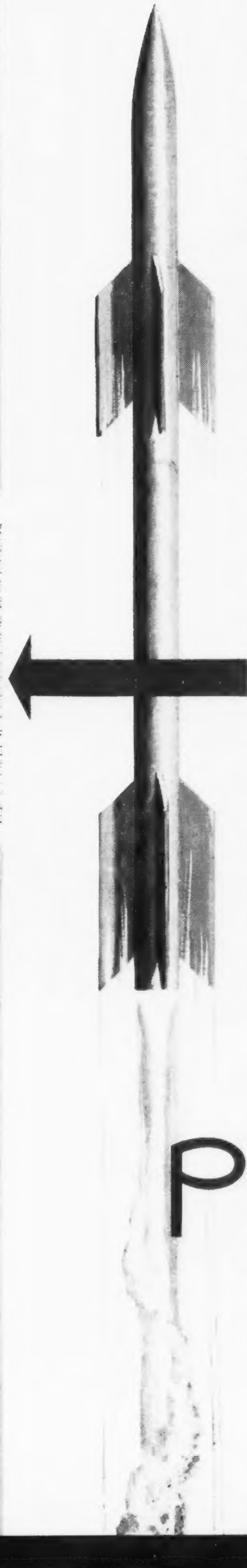
Astronautics

A PUBLICATION OF THE AMERICAN ROCKET SOCIETY

OCTOBER 1958


REACTION MOTORS Division of Thiokol
X-15
at
DENVILLE
New Jersey
Reaction Motors—America's first rocket company and an outstanding pioneer in the field of liquid propellant rocket engines—now, a part of Thiokol Chemical Corporation, is contributing important advances in rocket engineering. Developing power plants for the Air Force's X-15 manned rocket plant is one of the current projects. With the addition of Reaction Motors Division's experienced personnel and modern facilities, Thiokol has expanded its leadership in the design, development and production of rocket propulsion systems to both solid and liquid rocket engines.
Engineers, scientists—perhaps there's a place for you in Thiokol's expanding organization. Our new projects present challenging problems and the chance for greater responsibility.
Thiokol® CHEMICAL CORPORATION
TRENTON, N. J. • ELKTON, MD. • HUNTSVILLE, ALA. • BRISTOL, PA.
DENVILLE, N. J. • MARSHALL, TEXAS • MOSS POINT, MISS. • BRIGHAM CITY, UTAH
®Registered trademark of the Thiokol Chemical Corporation for its liquid polymers, rocket propellants, plasticizers and other Chemical products.



Do you know about Gask-O-Seals?

THIS Gask-O-Seal

EXCEEDS

HERMETIC

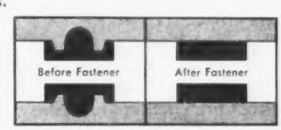
SPECS!

Gask-O-Seals often equal or *exceed specification for hermetic* sealing. The one shown here, for instance, has eight sealing points and is on one of our newest missiles. The leakage rate is less than the original *hermetic* seal specification called for which is about as perfect as any seal can be.

Gask-O-Seals are high and low pressure static seals which require NO groove machining to accommodate. A flat surface with only a 125 RMS surface finish is all you have to provide to get positive sealing with a Gask-O-Seal.

There are many other outstanding features about Gask-O-Seals: Limited area for fluid attack, no loss of structural strength, rigid, easy to install and replace, no tolerance build-up possible in seal cavity, etc.

Why not find out about Gask-O-Seals and the other seals of Parker Seal Company's "O-Seal Family"—by the makers of Parker O-rings.

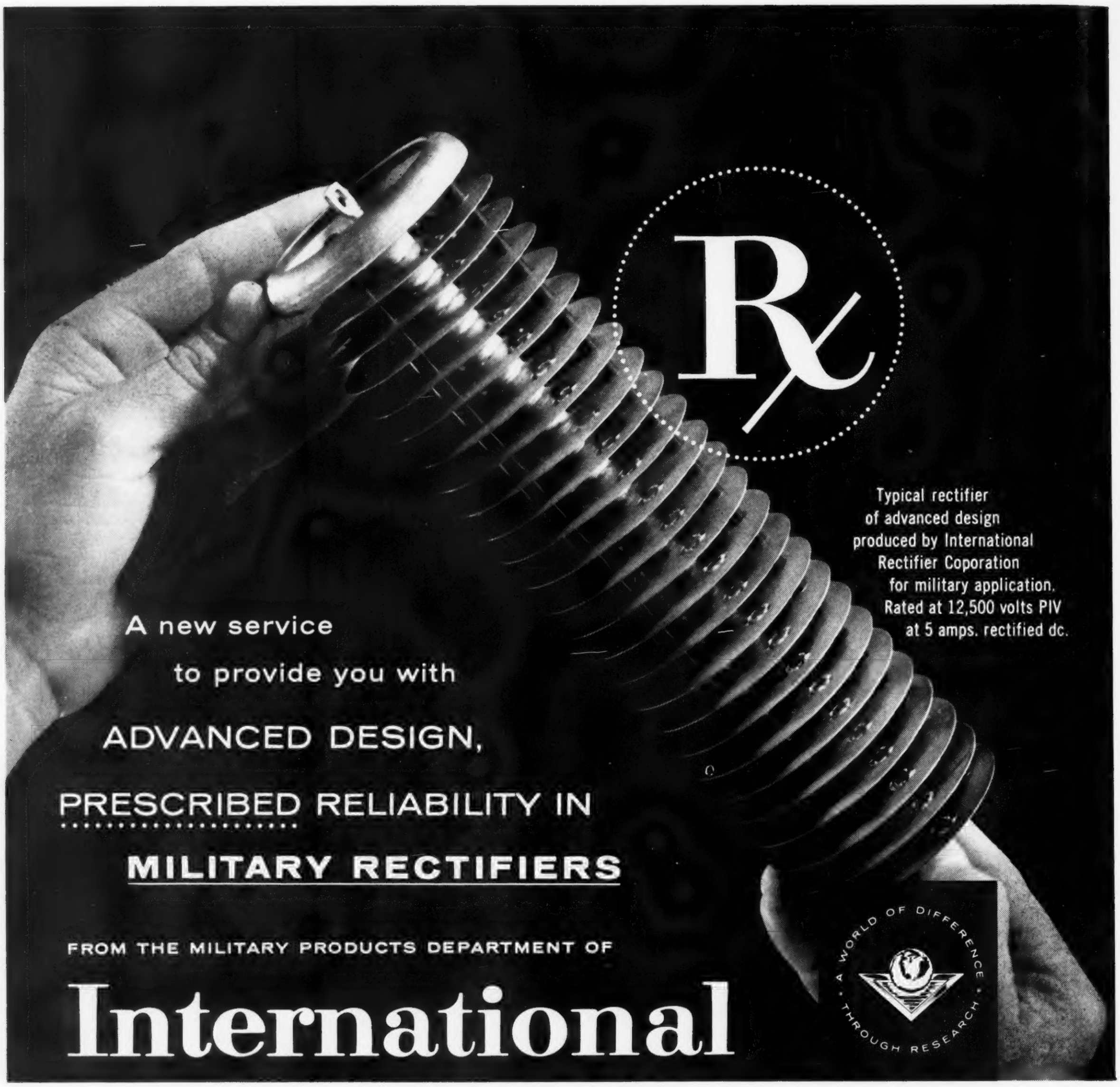


Parker
SEAL COMPANY

CULVER CITY, CALIF. • CLEVELAND, 12, OHIO

A DIVISION OF Parker Hannifin CORPORATION

(Formerly F. C. Wolfe Co. & Rubber Products Div. of Parker Appliance Co.)



Rectifier Corp.

PRESCRIBED RELIABILITY ... essential to space-age technology ... supplies you with enforceable procurement documents that prescribe the reliability needed, coupled with the engineering and manufacturing skills required to *deliver* rectifiers heretofore unavailable ... designed, manufactured and tested to perform within the prescribed specifications of the contract!

This concept is the basis for the development of highly reliable, ruggedized rectifiers now available through the Military Products Department of International Rectifier Corporation. Through advanced design and manufacturing techniques, this group can supply you with standard or special units, all manufactured to meet the most rigid military requirements, *plus* physical and electrical *reliability to any degree* ... prescribed by you, or by our own capable advisory group.

PRESCRIBED RELIABILITY SPECIFICATION SERVICE

To simplify your procurement, proposed specifications in the latest military style, containing as a part of the requirements the design and life-test pattern found to be correlated with known field failure rates, will be supplied to qualified customers without charge. These specifications will be written to include any degree of reliability in a manner enforceable as a procurement document.

Write for the 8 page brochure that describes the steps taken to achieve "prescribed" reliability and the tools supplied by International Rectifier to simplify your design and procurement problems. There is no obligation, of course.

ADDRESS INQUIRIES TO: MILITARY PRODUCTS DEPARTMENT, INTERNATIONAL RECTIFIER CORPORATION, EL SEGUNDO, CALIFORNIA

WORLD'S LARGEST SUPPLIER OF INDUSTRIAL METALLIC RECTIFIERS • SELENIUM • GERMANIUM • SILICON

Astronautics

A PUBLICATION OF THE AMERICAN ROCKET SOCIETY, INC.

October 1958 volume 3 number 10

EDITORIAL

FEATURES

NEWS

DEPARTMENTS

ASTRONAUTICS is published monthly by the American Rocket Society, Inc., and the American Interplanetary Society at 20th & Northampton Sts., Easton, Pa., U.S.A. Editorial offices: 500 Fifth Ave., New York 36, N. Y. Price $9.00 a year; $9.50 for foreign subscriptions; single copies $1.50. Second-class mail privileges authorized at Easton, Penna. Notice of change of address should be sent to Secretary, ARS, at least 30 days prior to publication. Opinions expressed herein are the authors' and do not necessarily reflect those of the Editors or of the Society.

Astro notes

SPACE EXPERIMENTS

• ARPA may abandon its moon-scanner experiment in one or both of the remaining AF lunar probes. Mounting curiosity about the exact composition, intensity and extent of the earth's corpuscular radiation field, coupled with negligible value of a chancy and, even if successful, crude photo of the other side of the moon, are main factors in "re-appraisal" of lunar vehicle instrumentation.

• Army's first "moon shot" may also be a misnomer. Army brass, mindful of guidance and control problems involved in project of this type, may aim their vehicle in the general direction of the moon and let 'er rip, hoping that, even if it misses its target by a wide margin, its velocity will be sufficient to send it past the moon and out into space, perhaps as far as 300,000 or 400,000 miles, to gather as much data as possible about the extent of the radiation band.

• Four more Vanguard shots remain after the attempt scheduled for mid-September to put the cloud-cover experiment in orbit. SLV-4 is committed to the 13-in. magnetometer experiment and NACA's inflatable subsatellite, with SLV-5 earmarked for the radiation-balance experiment. No experiments have been assigned as yet for SLV-6 or 7, although the latter is tentatively scheduled to utilize ABL's high-energy third stage to put as much as a 50-lb payload in orbit. The program will not be completed until next year, although IGY officially ends Dec. 31.

• Look for important findings from Project Eclipse, IGY program to study solar radiation with sounding rockets Oct. 12, just before and after eclipse at Danger Islands in South Pacific. Data may unify results from a variety of atmospheric studies at altitudes to 250 miles.

• Bearing breakdown in lox pump is said to have caused failure of Thor booster in August moon shot. Explorer V failed to orbit because booster under residual thrust rammed upper stages after separation.

• Sputnik II ended in the drink off coast of Brazil or in Brazilian jungles.

• The two dogs the Soviets brought to earth alive and in good health in a parachute-braked capsule ejected from a sounding rocket that reached 279-mile altitude strengthened expectations that Russia will try a low-altitude man-carrying satellite in the near future. Leonid Sedov, IAF vice-president and leader of the Russian IAF delegation, says this project has priority topping even firing of moon probe by U.S.S.R.

MISSILES

• With big facilities for methylamine production going onstream, more will be heard about UDMH and storable liquid rocket engines, small (see page 86) and large.

• Arthur D. Little and Minneapolis-Honeywell teamed to produce an automatic propellant-loading system for liquid missiles that cuts countdown time appreciably. Linde, moreover, will shortly announce exceptionally efficient means for insulating and rapidly transferring lox.

• AF Bomarc publicity brought defensive talk from Army authorities, who feel Army Nike-Hercules was unjustly disparaged in some newspapers. Permanent N-H installations guard New York, Chicago and Washington, D.C. areas, but Army has under development a mobile N-H launching system. Army countered

with announcement that a 450,000-lb thrust Thiokol motor for Nike-Zeus, the anti-missile expected to succeed N-H, was static-fired successfully recently.

INDUSTRY

• Marquardt has joined with Applied Radiation Corp. (ARCO) of Walnut Creek, Calif., to study electrical and ion propulsion for space flight. ARCO specializes in high-current linear accelerators.

• A newly formed nonprofit corporation, MITRE (MIT Research and Engineering), will service AF's Air Defense Integration Div. much as Space Technology Labs does for BMD. Move aims at freeing Lincoln Labs scientists for basic research.

BUDGET

• From $39 billion DOD budget, highest since 1953, AF will get $17.9 billion, Navy $11.4 billion, Army $9 billion. Navy leads in R&D funds, with $821 million slated as against $743 million for AF. ARPA drew $540 million, a whopping $240 million more than expected.

SPACE TALK

• In New York before IAF meeting, Theodore von Kármán said he thought U.S. might bring a man safely through re-entry, and land him in a designated area, three years after starting a development program for this purpose. At IAF meeting, Wernher von Braun gave five years for manned re-entry with controlled landing, as did Walter Dornberger early last summer.

• Vanguard on a Titan booster may constitute first Mars probe.

• International cooperation in astronautics drew support from U.S., through a resolution set before U.N. to bring space programs under its auspices, and from IAF, through a resolution calling for a special convention to discuss space law, a four-point program for cooperative projects, and a proposal for an international institute of astronautics.

R&D

• ARPA has directed the Army to develop a rocket engine with about $1^1/_2$ million pounds of thrust. Authorization follows prior assignment to AF for a powerplant in this range. Army, however, will cluster several engines to achieve the thrust figure and will probably complete the task before AF finishes work on its huge single-barrel motor. Most likely contractor for the Army job is Rocketdyne, also building the AF engine. Reason: Rocketdyne has already developed and test-fired components of 300,000-lb engine in which Army had a financial share.

• There's more than meets the eye in current AF research rocket shots at Cape Canaveral. NACA five-stage rocket (see page 22) is being used ostensibly to gather data on newly uncovered radiation belt at altitudes up to 800 miles. Work is being carried out by BMD as "agent" for ARPA, with large portions of the program highly classified.

• Westinghouse revealed that certain thermoelectric (mixed-valence) compounds give usable amounts of electricity for present satellite applications, and will be practical for power generation at 2000–3000 F within five years.

• Studies of matter in degenerate state near absolute zero with the giant electromagnet at UCal may advance radar, guidance and computer developments.

• Bell Aircraft reported static firing a large rocket engine with liquid fluorine as oxidizer under supervision of WADC's Lewis Flight Propulsion Lab, indicating fluorine systems are on the verge of becoming practical.

Advanced missile and

space projects

require **Engineers** *and*

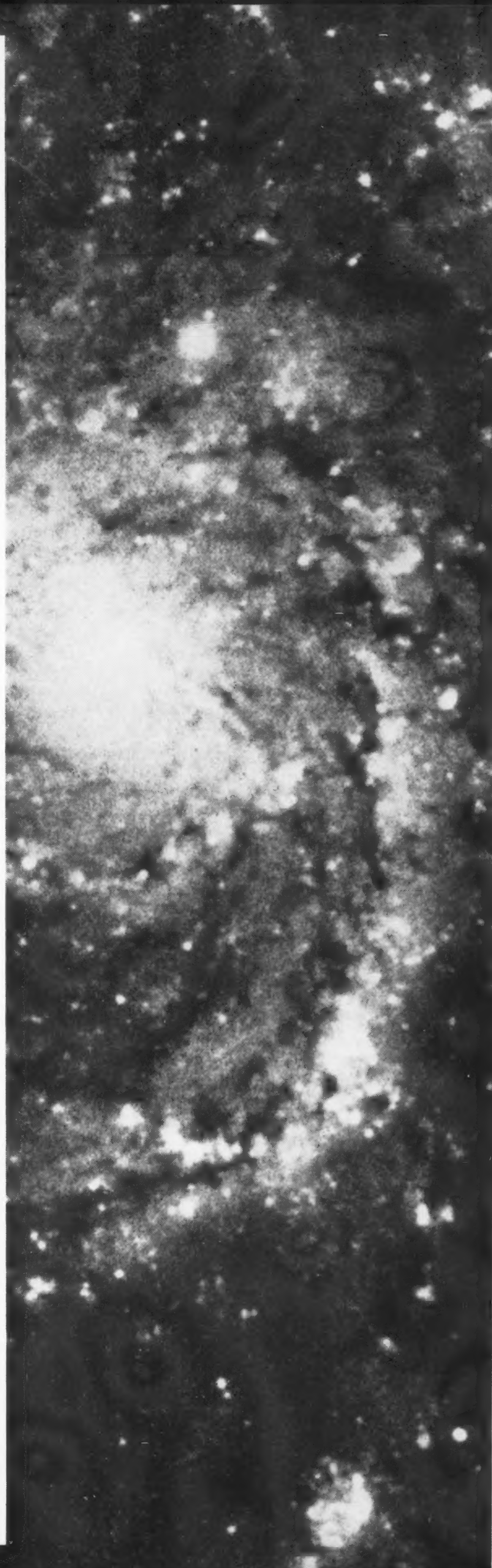
Scientists *to work on*

THE FRONTIERS OF SPACE

Lockheed Missile Systems Division, recently honored at the first National Missile Industry Conference as "the organization that contributed most in the past year to the development of the art of missiles and astronautics," holds such important, long-term projects as: the Navy Polaris IRBM, Earth Satellite, Army Kingfisher target missile, and the Air Force X-7 ramjet test vehicle.

To carry out such complex projects, the frontiers of technology in all areas must be expanded. Responsible positions in our research and development laboratories and in our project organizations are available now for high-level engineers and scientists.

If you are experienced in physics, mathematics, chemistry or one of the engineering sciences, your inquiry is invited. Please write Research and Development Staff, Sunnyvale 14, California. (For the convenience of those living in the East and Midwest, offices are maintained at Suite 745, 405 Lexington Ave., New York 17, and at Suite 300, 840 N. Michigan Ave., Chicago 11.)



Capital wire

News highlights from Washington

SPACE WEAPONS

• Military scientists are pondering the possibilities of lightweight particle accelerators as weapons against manned space satellites. They think it might be possible to produce vast increases in radiation intensity within the earth's geomagnetic trap. Such a weapon could produce storms of high-energy electrons in a very short time. The electrons would spiral around the earth's magnetic field lines, and penetrate even shielded satellites.

• The moon's potential as a reconnaissance satellite was a subject of discussion at the Amsterdam IAF meeting, much to the annoyance of Navy officers in the Pentagon. The Navy is building a $60 million radio telescope at Sugar Grove, W. Va., with a parabolic dish more than 400 ft in diam. Although NRL is generally believed to be in charge of the facility, this arrangement is merely a "cover" for one of the nation's lesser-known intelligence agencies. It is believed the Sugar Grove instrument will be sensitive enough to detect the reflected radio emanations of rocket motor exhausts and other heat sources by tuning in on the moon.

SATELLITES

• Dr. Wernher von Braun said a freak accident prevented Explorer V from achieving an orbit. After separation of the first stage from the remaining three stages, residual gases and liquids remaining in the Redstone rocket expanded in the vacuum of space, nudging it ahead with sufficient thrust to strike the upper stage package and prevent its proper injection into orbit. Special precautions will be taken in the future to prevent a recurrence.

RADIATION BARRIER

• Fred Singer, Univ. of Maryland physicist, proposed a novel means to neutralize the recently discovered radiation belt: Sweep it out with one or more large aluminum satellites. Singer conjectured that the radiation consisted of high-energy protons originating from decay of neutrons produced by cosmic ray bombardment of the atmosphere. Despite the measurements of 10 to 100 roentgens above 600 miles, Singer believes there are only a relatively small number of particles in the earth's geomagnetic trap. His figures indicate a total charged particle population of only 10 to the 16th, compared, for example, with a number like 10 to the 19th electrons per sec required to energize a 100-watt bulb.

Other scientists disagree with Singer, noting that evidence from the radio phenomenon called "whistlers" indicates an outer space ion density much greater than the level Singer suggests. Some believe that the Explorer satellites have merely scraped the lowest level of radiation intensity, and that the main belt will be found at an altitude of 20,000 to 80,000 miles. Singer believes it begins at 250 miles, reaches its maximum intensity at 6000 miles and fades away at about 40,000 miles distance.

Whatever the origin of the radiation belt, scientists generally were feeling more optimistic that it could be circumvented. They felt satellite orbits below 300 miles would be safe for human astronauts, and agreed with Singer that space ships could be launched into space on polar trajectories and thereby avoid most of the radiation flux. Declared Dr. Herbert York, Chief Scientist, ARPA: "At the very worst, it should be only several diameters of the earth wide and a space ship would be through it in several hours, certainly not long enough for a fatal radiation dose from what we know now of the band."

LUNAR PROBE

• Washington was disappointed but not discouraged at the failure of the Air Force's initial effort Aug. 17 to hurl an 84-lb instrumented package at the moon. Officials privately congratulated themselves for the deliberately pessimistic tone of their prelaunching statements, but at the same time braced themselves for another Russian space extravaganza. Most officials here believe the Russians can direct a fully guided probe at the moon any time they choose because of their superior launching capability. But reports from overseas, and particularly from the IAF meeting in Amsterdam, persistently indicated the Russians were planning to fire a man into space in the relatively near future. This theory was given support by the Soviet announcement that it has safely recovered two dogs launched 281 miles into space by a single-stage rocket.

• Chief consideration in the timing of the USAF lunar shots is the requirement that the nozzle of the fourth-stage retro-rocket in the moon probe be pointed at the correct angle when the probe approaches the moon. This is about 50 deg clockwise of the vehicle's trajectory across the moon's orbit. Since the entire probe is spin-stabilized and cannot be adjusted after it leaves the earth, it must be launched during the three or four days when it will be oriented at the proper angle on approaching the moon.

MISSILES

• The Air Force has quietly recovered instrumented capsules from two Thor missiles fired more than 1200 miles at Cape Canaveral June 13 and July 12. The capsules utilized inflatable buoys, salt water-actuated radio transmitters, SOFAR bombs and related gear to aid recovery. Weighing some 20 lb each, the General Electric capsules contained tape records of the same data on nose cone performance telemetered to range stations during re-entry. They were recovered about the same time the airmen failed to retrieve two mouse-inhabited Thor-Able nose cones launched into the South Atlantic during the summer.

• The Navy is continuing to support development of the guidance system slated for the defunct Triton ramjet missile Triton was canceled in the financial squeeze last year, but the Applied Physics Laboratory of Johns Hopkins has continued to work on its "Atranertial" guidance system with Goodyear Aircraft Corp. and Kearfott Co., Inc., subsidiary of General Precision Equipment Corp.


Missile Metal Machining

For the record—

The month's news in review

Aug. 1—AF reveals development of a jam-proof, all inertial ICBM guidance system by Arma Div.

—Army discloses Pershing IRBM will be a two-stage weapon with inertial guidance system.

—AEC announces test detonation of a nuclear warhead at high altitude over the Pacific, reportedly using an Army Redstone for its vehicle.

Aug. 2—AF successfully gets off its first Atlas ICBM with full propulsion system to a distance of 2500 miles.

—NAS forms 16-member Space Science Board to be directed by Lloyd V. Berkner.

Aug. 6—Preliminary analysis of data from Explorer IV indicates radiation 167 times more intense than encountered by earlier satellites.

Aug. 7—Bomarc missile is successfully launched in Florida by remote control from N.Y., but fails to hit its target.

—AF balloon carrying animal life rips apart at 60,000 ft.

Aug. 8—Atomic sub Nautilus becomes first craft to sail under the polar ice cap, doing 1830 miles in record four days.

—Pres. Eisenhower names T. Keith Glennan to head NASA and Hugh L. Dryden as deputy chief.

—House votes four-year, $900 million aid to science education bill, but deletes Federal scholarship provision.

Aug. 9—Fifth and last IGY assembly ends and resolves to continue in 1959.

Aug. 12—Second U.S. nuclear sub, the Skate, sails under North Pole.

Aug. 14—Senate Space Committee okays nominations of T. Keith Glennan and Hugh L. Dryden.

Aug. 17—AF moon shot fails, going less than 10 miles.

Aug. 19—East-West scientific conferees agree on detection system for monitoring international ban on nuclear weapon testing.

Aug. 20—Nuclear sub Triton is launched.

Aug. 23—AF says Explorer IV data indicates a 250-mile-high safety zone above the earth in which manned satellite travel is possible.

—Congress okays science education bill, sends it to President for his signature.

Aug. 24—Army's Explorer V fails to orbit.

Aug. 27—Army discloses it has test fired a rocket motor having several hundred thousand pounds of thrust.

—Bell Aircraft says it has successfully tested a rocket engine using liquid fluorine as an oxidizer.

—Soviets announce firing of rocket containing two dogs 281 miles high, and returning them safely back to earth.

Aug. 30—Wernher von Braun explains Explorer V failure as caused by high-altitude collision between parts of its rocket units.

Missiles designed to soar out of this world

...are sped by liquid oxygen from LINDE

Oil, kerosene, and alcohol "burn" by combining chemically with oxygen from the air. But it takes pure oxygen with these fuels to speed rocket planes faster than sound . . . to drive missiles beyond the earth's atmosphere.

Liquid oxygen, vital to today's rocket engines and many types of missiles, was being produced by LINDE as long as 25 years ago. In fact, LINDE has been supplying oxygen to industry for more than 50 years. LINDE pipes oxygen directly to industrial users from nearby oxygen plants built and operated by LINDE. The user makes no capital investment, and pays only for the oxygen consumed —at a price guaranteed by LINDE.

LINDE also developed methods for transporting liquid oxygen efficiently, in large and small amounts, at 300 degrees below zero F. You can get LINDE oxygen in just the quantity you need, at the exact time and place you want it, as a liquid or a gas.

For detailed information about LINDE oxygen, write Box AA-10, LINDE COMPANY, Division of Union Carbide Corporation, 30 East 42nd Street, New York 17, N. Y. Offices in other principal cities. *In Canada:* Linde Company, Division of Union Carbide Canada Limited.

When you need Oxygen—call LINDE!

The terms "Linde," "Driox," and "Union Carbide" are registered trade-marks of Union Carbide Corporation.

Liquid oxygen from LINDE's DRIOX oxygen units is teamed with liquid fuels to propel missiles and rocket planes.

Linde
TRADE-MARK

UNION CARBIDE

COVER: *Sheer luck was responsible for this dramatic photo of a Bomarc firing at Cape Canaveral (see page 34). Sequence camera was set up some time before scheduled launching and, in the meantime, workmen placed some heavy screens between the camera and launcher unnoticed by Boeing camera crew. The result was this striking shot.*

Astronautics

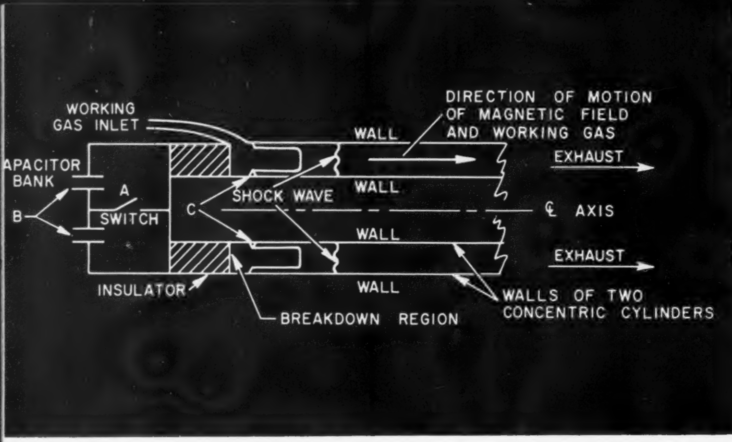
OCTOBER 1958

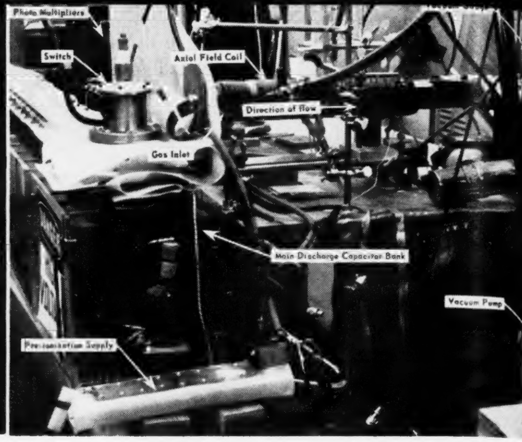
The Janus Head

The world changes by both action and implication. A year after Sputnik I, it seems topical to hear Wernher von Braun describe Jupiter-C in some detail; to hope with a propellants man that someone will come up with a nice hot solid that burns cleanly; to feel accomplishment with an instrumentation engineer that he will get static-firing data good to ± 1 per cent most of the time; to take a visitor's peep at an NACA-built facility. Jupiter-C put a satellite into orbit, but it showed the plateau of our practical propulsion technology. A year of astronautics did not make the gas generator a thing of beauty. Good data on captive-rocket tests still costs much in time and investment. Langley Field underscores the momentum of the past.

Not dismayed, the mind leaps ahead to space—conjures physics to push space flight, drags up Lagrange to set a satellite, calculates what power man can draw in space.

All of which is to say that this issue of ASTRONAUTICS reflects the uneasy shifting of our time from a decade of missiles to the age of space flight. We have both gas generators and magnetohydrodynamics, Bomarc and synodic satellites, data processing for ground tests and a survey of power sources in space—ironic conjunctions, epitomized by Jupiter-C.

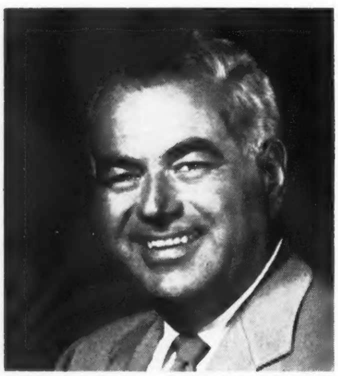




Left, schematic of ARL pulsed magnetic accelerator experiment, and (right) experimental setup used in the lab. Toroidal shock wave is formed between concentric glass cylinders (top foreground) and accelerated by magnetic field. Gas velocities of 500,000 mph have been obtained.

Introducing magnetohydrodynamics

Research in this area is leading to new space propulsion systems, as well as re-entry "drag devices" and electric power generators



Arthur Kantrowitz received his B.S. and M.A. degrees at Columbia Univ. in 1934 and 1935 respectively, and returned to Columbia to receive his Ph.D. in 1947. A physicist with NACA from 1935 to 1946, Dr. Kantrowitz was associate professor and professor of aeronautical engineering and engineering physics at Cornell from 1946 to 1956 and a visiting lecturer at Harvard in 1952. He has been director of the Avco Research Lab since 1955 and a vice-president and director of Avco Mfg. Corp. since 1956. He has been a Fulbright and Guggenheim fellow and visiting institute professor and fellow in the MIT School for Advanced Study, is a fellow of the AAAS and past chairman of Fluid Dynamics Div. of the American Physical Society.

The following article identifies several different possible applications of magnetohydrodynamics (MHD) and describes the research of our Laboratory in these fields. MHD is an exciting area of study, and we are convinced that the next few years will bring forth practical applications of great potential. The American Rocket Society *is to be congratuated on its recognition of this potential by formation of an MHD Technical Committee.*

Arthur Kantrowitz
Director, AVCO Research Laboratory
Everett, Mass.

DURING THE past few months, the term magnetohydrodynamics (MHD) has appeared in the public press with increasing frequency. Variously referred to as MHD, hydromagnetics, magneto gas dynamics, or magnetoaerodynamics, recent research has resulted in an appreciation of some important and significant implications of the subject. Four specific applications of magnetohydrodynamics in two major areas have been identified and are being studied at the Avco Research Laboratory (ARL). These are:

A. *Flight magnetohydrodynamics*
   1. Space flight propulsion
   2. Re-entry "drag device"

B. *Electric power generation*
   1. Low-temperature MHD (combustion process)
   2. High-temperature MHD (fusion)

In recent years, considerable interest has developed in the study of the interaction between magnetic fields and the flow of electrically conducting fluids or gases. As is well known, gases at high tempera-

tures become ionized, i.e., outer shell electrons are detached. Ionized gases conduct electricity and can be acted upon by magnetic fields. Initial interest in magnetohydrodynamics was spurred by astronomical observations, such as solar flares, and, recently, by problems associated with the fusion reactor.

May Unite Branches of Physics

Another source of current interest in magnetohydrodynamics is that the field offers an opportunity to unite two scientific disciplines—gas dynamics and electromagnetic theory. Until now, these subjects have had very few points of contact other than the similarity of some of their mathematical formalism. Both disciplines are individually well elaborated and cover great varieties of phenomena.

The variety of the phenomena of gas dynamics is limited by the simplicity of the physics involved. A great new group of reactions appears when the electrical properties of gases begin to become important in gas dynamics problems. Similarly, the simplicity of electromagnetic theory, which depends upon its linearity, will also disappear because of the essential nonlinearity of gas dynamics. The result is the prospect of a richness of new phenomena which can be only dimly appreciated at the present time.

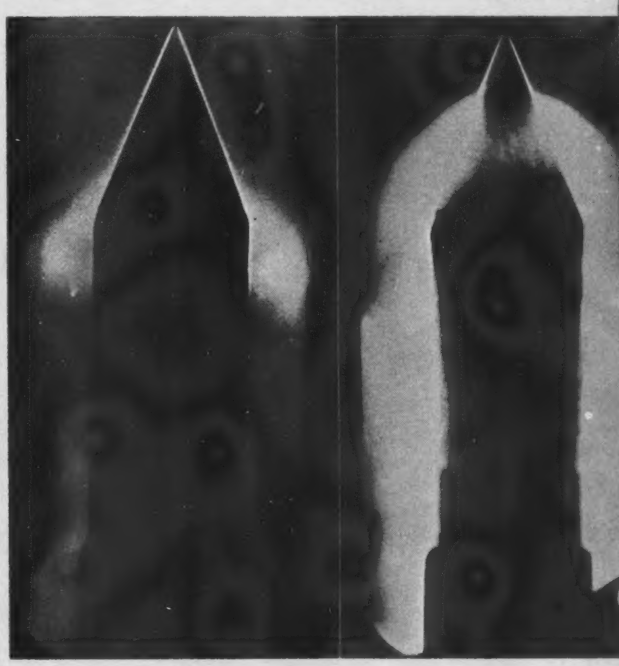
Some evidence of this richness has recently developed. Some examples are the production of high-energy particles in intense pinched sparks, as presented by Kurchatov, and the hypothesis of Gold that the sudden commencement of magnetic storms is related to the propagation of a shock wave produced by solar disturbances which may extend to the vicinity of the earth.

Laboratory Apparatus Designed

Interest in magnetohydrodynamics has stimulated various groups to design apparatus which can produce MHD phenomena on a laboratory scale. Experiments to establish the reality of Alfven's magnetohydrodynamic waves were conducted in his laboratory with liquid metals. The earliest gaseous MHD experiments were built around the pinched electrical discharge.

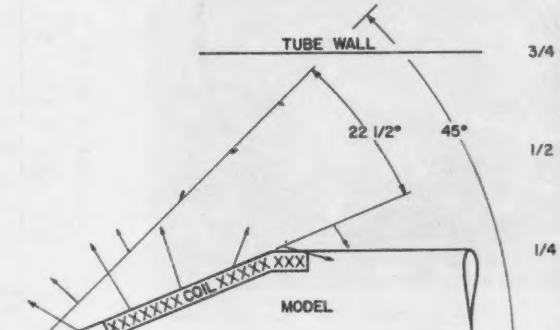
More recently, the production of ionized gases in shock tubes has provided a useful means for producing uniform regions of high-temperature gas of known density and enthalpy, and this tool has been employed for quantitative experiments. The substitution of an electromagnetic driver for the high-pressure gas drivers used in ordinary shock tubes has recently provided a tool which has the high-

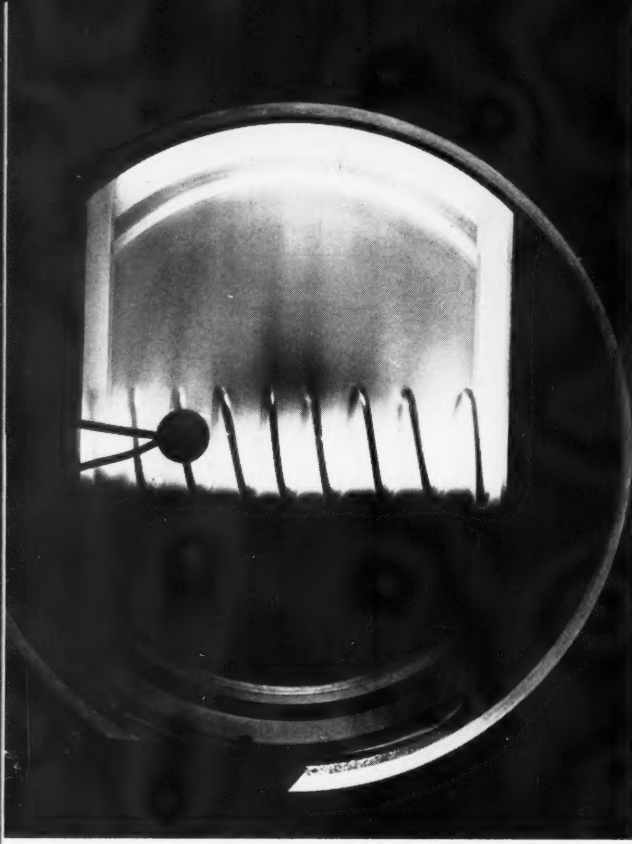
An MHD Experiment ... and What It Means



In the experiment, a pointed-nose model containing a coil winding was photographed in a shock tube. Photo at left shows typical shock wave configuration on a pointed body, while photo at right shows displaced shock wave caused by magnetic field generated by passing current through the coil, position of which is shown in schematic below.

The photos graphically illustrate the effect of a magnetic field through which ionized particles are passing. In the case of a re-entry vehicle, this would be expected to result in braking or drag action, as well as possible reduction in heat transfer to the body because of the displacement of the shock wave away from the vehicle.





Shock tube photo shows interaction of high-velocity ionized gas with solenoidal magnetic field. Gas is flowing from left to right at 10,000 fps at simulated altitude of 160,000 ft, with 1-in. coil creating magnetic field of 12,000 gauss. Photo provides visual representation of MHD flow phenomenal.

temperature capabilities of the pinched sparks, along with greater geometric flexibility. This device leads us to anticipate a more quantitative knowledge of the gas state than that which has been available.

Recent successes in laboratory experiments lead to the hope that practical devices will be forthcoming to utilize this anticipated richness of new phenomena in gaseous magnetohydrodynamics.

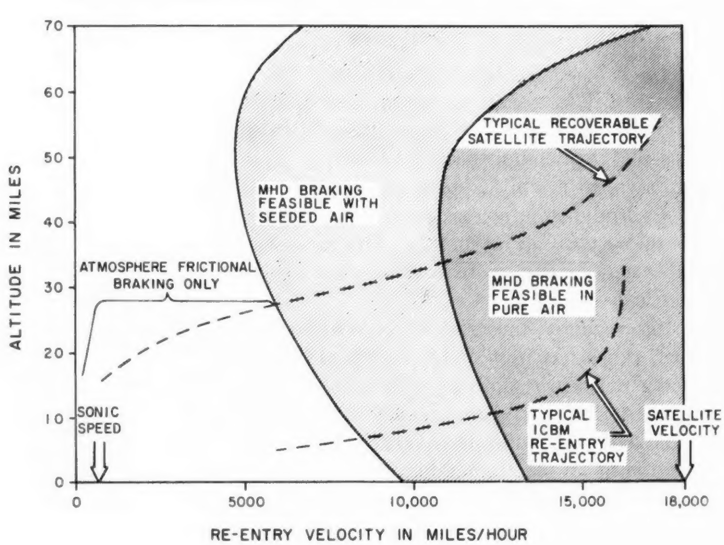
In the field of MHD space flight propulsion, a device has been constructed at ARL which uses a magnetic field to accelerate ionized gases to high velocities. The idea of electromagnetic acceleration of matter is an old one, dating from the discovery of electromotive laws by Faraday.

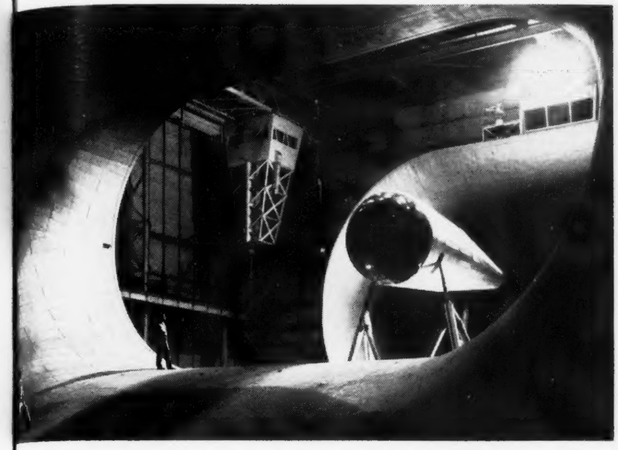
In the ARL gas accelerator, the annulus between two concentric cylinders provides a space in which the gas is accelerated in the direction of the axis of the cylinders. A schematic diagram of the apparatus is shown at the top of page 18. In operation, the annular space between the two cylinders is evacuated, and the working gas is admitted from a storage supply. When switch A is closed, the high-voltage condensers B are discharged. This high voltage causes a "breakdown," or ionization, of the low-pressure gas at point C.

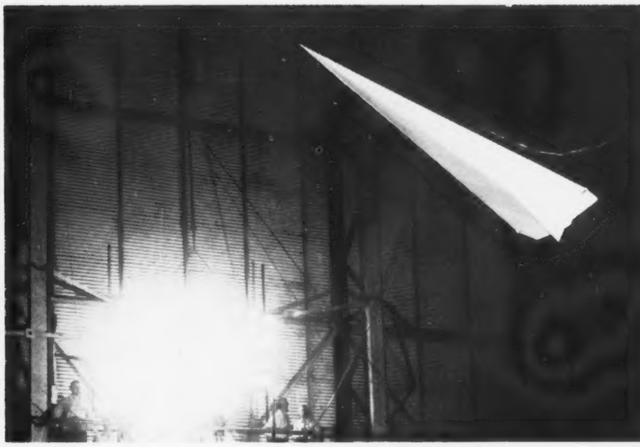
The electrically conducting ring of gas between the walls of the two cylinders at C is accelerated to the right during the discharge cycle of the capacitor bank. Preceding this mass of gas is a shock wave which, as it moves at tremendous speed, heats the gas ahead of the driving current to a temperature high enough to cause ionization. Thus the gas becomes a conductor. (CONTINUED ON PAGE 74)

Conceptual design of a re-entry vehicle which would use MHD braking.

Flight Regimes in which MHD Braking Appears Feasible







Full-scale wind-tunnel, originally designed for tests of conventional aircraft, is now used for ballistic missile and space vehicle studies. At left, model nose cone is readied for laminar air flow test; at right, hypersonic glider model is flown by remote control in stability study.

NASA Langley Aeronautical Laboratory

On the frontier of flight

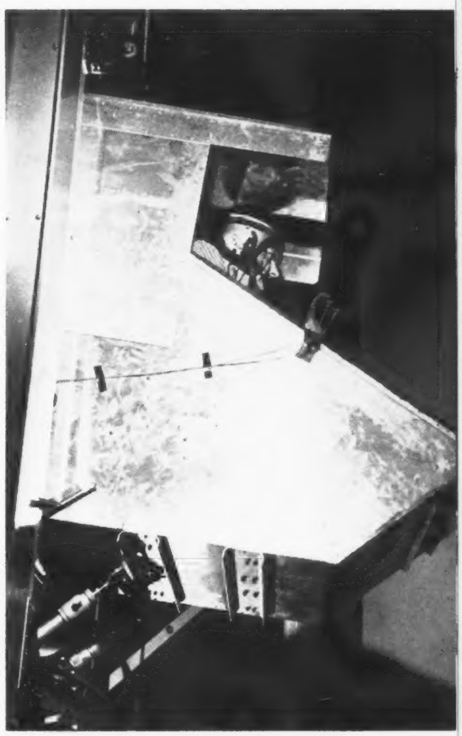
EACH DAY, some 1000 scientists and engineers move on the frontier of flight at the original and largest of NASA's three major research centers, Langley Aeronautical Laboratory at Langley Field, Va. Reflecting both its inception in World War I, when it was established by the government, and today's race into space, Langley provides facilities for research throughout the flight corridor—from subsonic to hypervelocity speeds—and on problems of re-entry and space flight.

These facilities, representing an investment of $100 million, include 30 major wind tunnels, laboratories and testing complexes; a dozen shops for instrument construction, model building, wood working, machining and sheet metal work; and offices and other supporting buildings.

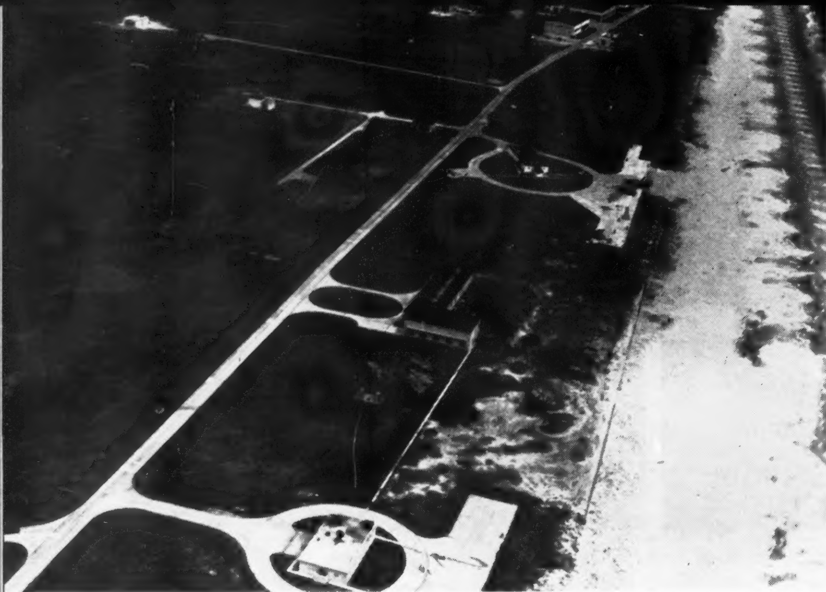
Free-Flight Testing at Wallops Island

Operated in conjunction with the laboratory is one of NASA's two field stations, the Pilotless Aircraft Research Station at Wallops Island, off the eastern coast of Virginia. This station, established in 1945 to obtain aerodynamic data at transonic and low supersonic speeds, now serves as a free-flight testing site for instrumented rocket-powered research models, which deliver data vital to the design of aircraft, missiles and space vehicles.

The pictures on these pages suggest the range of studies at NASA's Langley-Wallops Island complex, from the giant conventional wind tunnel, now being used to study such things as hypersonic gliders at subsonic and transonic speeds, to the scientist with his eye on the fundamental problems of re-entry.

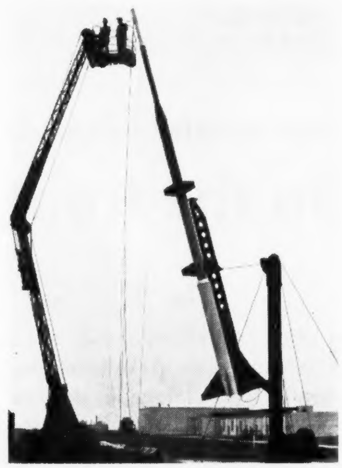


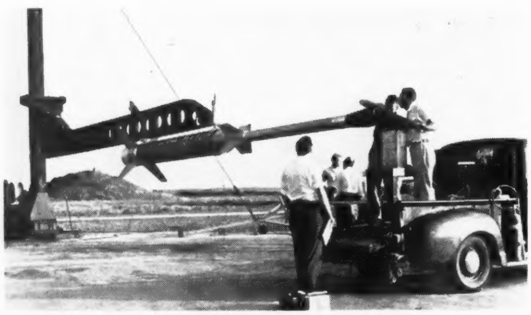
Human factors also come in for study at the lab. Here, response of a pilot to accelerations during vertical and pitching motions at hypersonic speeds is tested.



Aerial view of Pilotless Aircraft Research Station at Wallops Island, Va. Operated by Langley Lab, it is one of two present NASA field stations.

Five-stage research rocket below reached speed in excess of 8000 mph in Wallops re-entry test. Developed by NACA, the vehicle consists of an Honest John first stage, Nike booster second and third stages, a Recruit fourth stage and a Thiokol T-55 fifth stage. Rocket was boosted to 100,000 ft by first two stages, then accelerated downward from top of trajectory by final three stages, firing in sequence, to simulate re-entry.





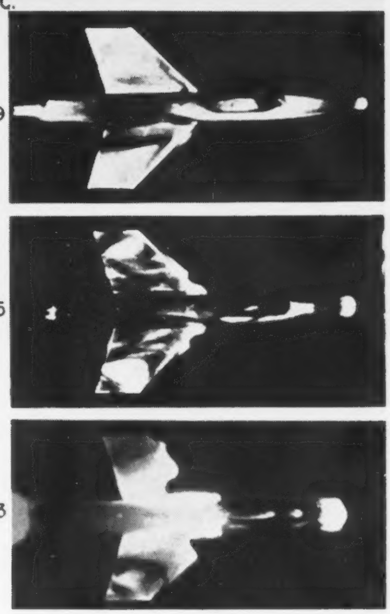
Nike-Cajun, developed by NACA at Wallops for exploration of upper atmosphere during IGY, is readied for firing.

Langley scientist adjusts instruments in free-flight research model to be flown in Wallops test. Telemetry section is in foreground, with battery pack located immediately behind it.

This aluminized plastic sphere, developed at Langley, has been accepted for IGY sub-satellite experiment. Shown collapsed and inflated, the sphere is to be used for air density measurements in the upper atmosphere.

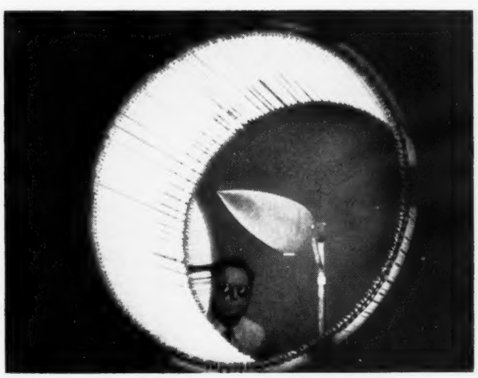
Langley scientist studies model nose cone subjected to 12,000 F temperature environment in arc-powered supersonic air jet as part of the lab's high-temperature materials research.

SEC.
.9
2.5
5.3

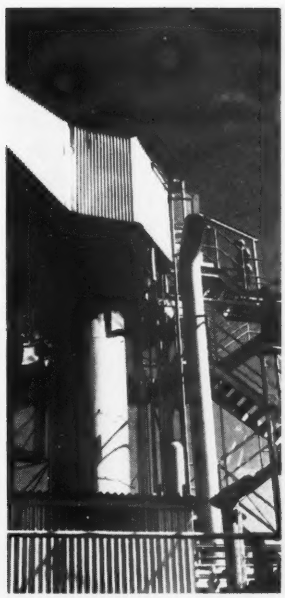


16 mm film strip of aerodynamic heating test shows what happens to stainless steel model subjected to exhaust from small acid-ammonia rocket. Gas jet reached exit velocity of 7000 fps during the test.

Wearing an aluminized protective suit, technician checks a model rocket glider in one section of the Langley unitary plan wind tunnel, where air can be heated to 400 F by moving it at speed of 3500 mph.

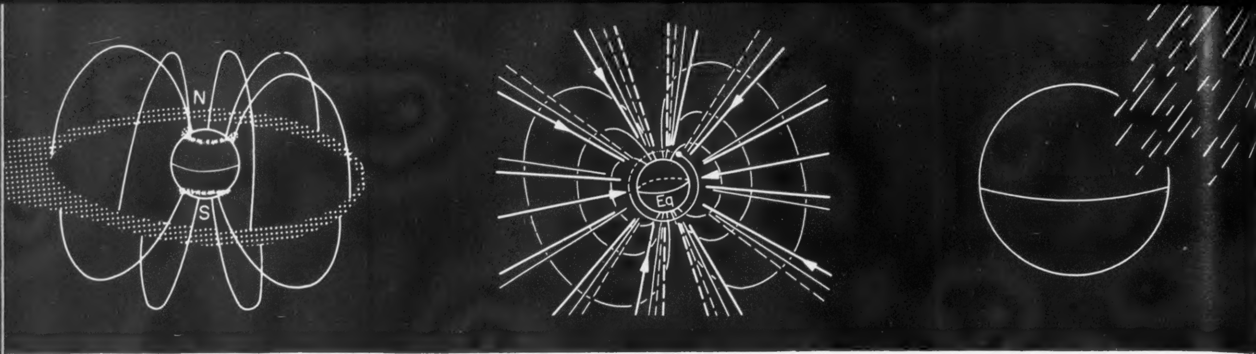


Scientist, standing behind glass shield and wearing protective goggles, studies model nose cone exposed to simulated aerodynamic heating conditions in cylindrical radiator incorporating 225 quartz-tube heat lamps.



Pilot-model high-temperature jet facility, used for materials testing and aerodynamic heating and re-entry studies, provides 4000 F airstream from 4 to 10 in. in diam in the test section, located in corrugated metal structure at top.

Missile model ready for testing in a test section of the unitary plan wind tunnel. Models are mounted with wings vertical and attached from aft end to a sting, through which pressure tubes and electrical leads pass to data equipment outside.



Ionized gas and magnetic fields **Cosmic rays** **Meteoroids**

Sources of power in space free for the taking, but which man as yet has little practical means for utilizing, include magnetic fields, cosmic rays, ionized gas clouds and meteoroids.

What power sources in space?

Although nature provides such potential power sources as meteoroids, cosmic rays and solar radiation, there are today few practical means of using them... Consequently, man will probably have to carry along his own sources of power in the form of chemicals or nuclear reactors

By John H. Huth

THE RAND CORP., SANTA MONICA, CALIF.

John H. Huth is a member of the senior staff of Rand's Aeronautics Dept., where he is currently working in aerodynamics, astronautics and energy sources. Between 1934, when he graduated with a degree in mechanical engineering from the Univ. of California, and 1950, when he received a Ph.D. in engineering mechanics from Stanford Univ., he held research positions with the UCal radiation lab, the Office of Scientific Research and Development, GE, Morris Dam group, and Stanoling Oil and Gas Co. Dr. Huth joined Rand in 1950. His varied experience includes work on induction-motor vibration, pressure-recording devices, thermal control of meters, design of electrical filters and timers, and aerodynamics.

WHETHER man enters space personally or through instrumented probes, he will find an ever-increasing need for power, and especially electrical power.

At the mean distance of Mars at closest approach, for example, even a narrow bandwidth telemetering link might easily require 200 kw. Also, space vehicles with ion propulsion will require many megawatts of electrical power, and from equipment much less bulky than anything currently available.

High accelerations, extreme temperatures, meteoroids and, especially, long periods of unattended operation present challenges in the design of space power systems. On the other hand, advantage may be taken of such special features of outer space as its ready-made vacuum. In fact, nature provides power in space, free for the taking. But, as usual, the taking is quite difficult.

If we were to sample "space," we would find thermal and corpuscular radiation, meteoroids, ionized gas clouds and some magnetic fields. All represent forms of energy, but at present we only know how to utilize the thermal radiation. The total flux of meteoroids, for instance, is very small (over 20 magnitudes only about 10^{10} of the solar constant). Consequently, unless one has mastered the art of matter annihilation, and we do not foresee how to do this, meteoroids are not a very attractive source of energy. The density of protons and electrons may in places run as high as 1000 particles per cc; but the probability of creating a fusion reaction with them to generate power is extremely small. The only other possibility is

to combine electrons and protons to produce hydrogen. And even if one could combine all the particles per unit volume in this fashion, the energy density would still be several orders of magnitude below the density of solar thermal energy.

The energy density of cosmic rays is also well below the thermal-energy density, and we do not know how to utilize such energetic particles (on the order of a billion electron volts). About the only hope on the horizon seems to be a very slim chance of converting some of them to light through absorption in organic materials.

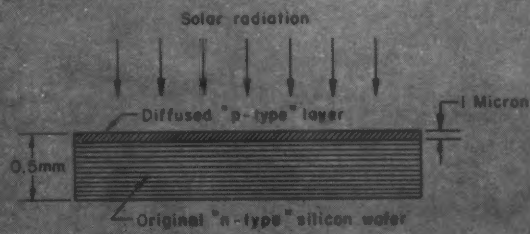
As to magnetic fields, they may have a high absolute energy density in space, but most schemes for utilizing these fields operate on their gradient.

We can make use of solar thermal energy in at least three ways: By allowing radiation pressure to act on a "sail," by concentration and conversion to heat, and by conversion directly to electricity through a quantum process.

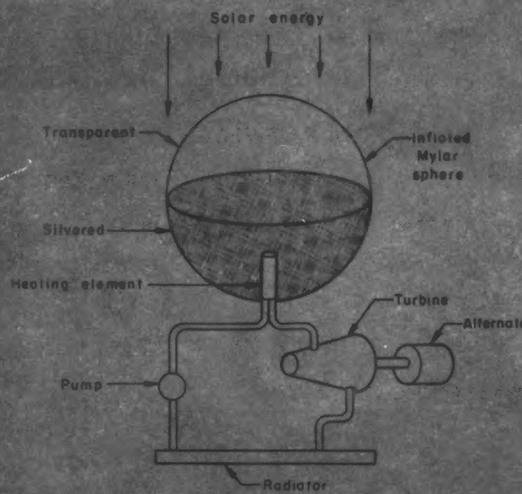
The magnitude of the radiation pressure normal to a perfectly reflecting sail equals $2W/c$, where W is the energy incident per unit area per second and c is the velocity of light. In the vicinity of the earth, this pressure amounts to about 1.2×10^{-9} lb per sq in. It is immediately evident that very large areas are required for appreciable forces. Furthermore, construction must be very light if one is to use a "solar sail" to accelerate a ship. For example, if our sail weighs only 5×10^{-4} gms/cm^2 of surface area, the resulting acceleration would be about 1.6×10^{-4} g. It should be noted finally that the efficiency of devices dependent on the action of radiation pressure against moving blades is proportional to the ratio of blade velocity to the velocity of light, and that, of course, solar radiation is much more diffuse at even Martian distances from the sun.

Hard To Concentrate Solar Energy

Concentration of solar energy for heating purposes suffers from many of the same difficulties as the "solar sail." Areas must be large, and structure must be lightweight yet sufficiently rigid to withstand acceleration. One proposal involves the utilization of spherical mirrors to heat a propulsive working fluid, as illustrated by the diagram on this page. The mirrors would be "mylar" (a tough plastic) balloons silvered over half of the inner surfaces. Temperatures of the order of 3500 K can be attained this way, but to enable one gram/sec of hydrogen to deliver a specific impulse of 1500 sec would require a minimum mirror cross-section of 150 sq meters. Furthermore, there is some evidence that mylar tends to become cloudy and brittle after several months exposure to solar radiation. An alternative type of con- (CONTINUED ON PAGE 62)



Silicon solar cells of this kind are used in the Vanguard satellite designs and should serve as a secondary source of power in space vehicles.



Balloons, half silvered to form collecting basins for solar radiation, might provide enough heat to drive a working fluid for propulsion, but they would be very large and possibly too fragile to allow good accelerations.

Energy Sources

Reaction	Energy release, ergs/gm	Fraction of mass converted to energy
Chemical ($H_2 + {}^1/_2O_2 \rightarrow H_2O$)	1.33×10^{11}	1.48×10^{-10}
Super-chemical: ($H + H \rightarrow H_2$)	2.2×10^{12}	2.45×10^{-9}
Nuclear fission (complete)	7.1×10^{17}	7.9×10^{-4}
Nuclear fusion	3.6×10^{18}	4.0×10^{-3}
Mass annihilation	9×10^{20}	1

Isotope Specific Powers

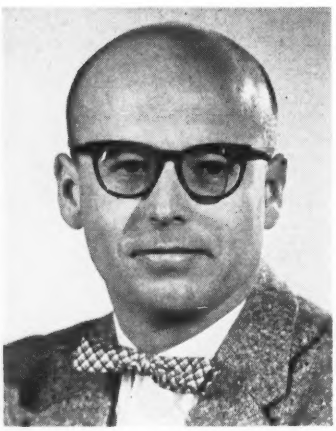
Isotope	Specific power of fresh isotope, watts thermal energy/gm	Half-life
Pm^{147}	0.345	2.6 yrs
Ru^{106}	29.800	1 yr
Po^{210}	141.000	138 days

Low-cost meteorological rocket systems

Development of simple, practical systems of the type described here, in which expendable equipment could be held to about $155 per firing, would prove mutually beneficial to both meteorology and rocketry

By I. G. Poppoff

STANFORD RESEARCH INSTITUTE, MENLO PARK, CALIF.



I. G. Poppoff is currently a senior physicist in the atmospheric chemical physics section of Stanford Research Institute, where he is engaged in research in the field of atmospheric physics. Prior to joining the SRI staff in 1953, he was with the U.S. Naval Radiological Defense Laboratory, where he conducted research related to radioactive fallout from nuclear weapons. A graduate of Whittier College, he has done graduate work in physics at the University of California and at Stanford University. During World War II, he served as an electronics officer with the Army Air Force. He is a member of the American Meteorological Society, American Rocket Society and the Optical Society of America.

PRESENT ROUTINE meteorological balloonsonde observations are limited to altitudes of 60,000 to 80,000 ft. With care, the observational ceiling of balloons can be raised to 100,000 ft under favorable conditions, and soundings over 120,000 ft have been reported.

Little is known of meteorological parameters above 80,000 ft, but by extrapolating the results of occasional higher balloon soundings and combining them with results obtained from occasional research rocket soundings, model atmospheres have been constructed which have proved to be useful in upper atmosphere studies. However, for applications that require a detailed knowledge of upper atmosphere wind and temperature profiles, there are no adequate sources of information.

Forecasting probable radioactive fallout patterns in connection with nuclear tests is a prime example of a field in which a detailed knowledge of upper atmosphere winds is required. The increasing operational altitudes of military aircraft is also increasing the need for upper atmosphere wind data. A knowledge of upper atmospheric conditions would be a material aid in evaluation of test results from missile launchings.

The use of small rocket vehicles to carry meteorological instrumentation into the upper atmosphere is an obvious solution to the problem of achieving reliable routine soundings above 100,000 ft. Preliminary experiments have been conducted by both Army and Navy research groups. These tests involved ejection of chaff or small metalized parachutes from small rockets. Subsequent tracking by radar provided information on the velocities and directions of upper atmosphere winds.

Poses Technical and Economic Problems

The suitability of rocketsondes for *routine* meteorological observations involves both technical and economic considerations. Of primary interest, of course, is whether or not simple meteorological rocketsonde systems are actually capable of providing useful data. Equally important, however, is whether a technically reliable rocketsonde system can be developed for a reasonable cost and the expendable units mass produced inexpensively.

Recently, a study was made for the Federal Civil Defense Administration to determine the feasibility of developing a rocketsonde system for routine meteorological use. The system requirements were to provide wind data and, if possible, temperature, pressure, and humidity data for altitudes up to 150,000 ft. In addition, the system was to be capable of integration with Weather Bureau facilities at minimum expense.

The simplest rocketsonde system would be a single-stage solid-propellant rocket carrying minimum instrumentation aloft to the desired maximum altitude, at which point the instrument container could be separated from the rocket vehicle and allowed to descend by parachute. Meteorological information would be obtained during the descent. This operation is illustrated schematically in the drawing on this page.

Wind velocities and directions would be determined by tracking the drafting parachutesonde during its descent, and temperatures would be obtained as telemetered information from a suitable reflective thermistor exposed to the atmosphere. Initially, no provision need be made for measurement of pressure and humidity, since the present state of development of these sensing elements is not satisfactory. However, inclusion of pressure and humidity elements can be considered as an ultimate goal in the development of rocketsonde systems, and a parallel development of such elements would be profitable.

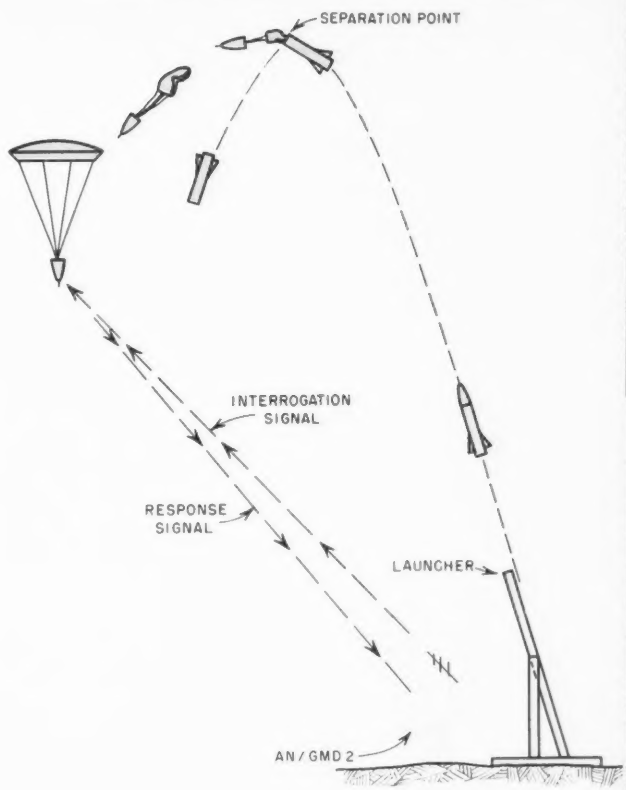
To determine the instantaneous altitude of a descending sonde without a pressure sensor, the slant range and elevation angle must be determined. Two tracking systems are available that could provide the necessary slant range information: Radar and the AN/GMD-2 rawinsonde system.

Advantages and Disadvantages

The use of radar in tracking metalized parachutes could lead to a simple, inexpensive sonde, particularly if only wind data were required. Radar tracking would also have some disadvantages. Since the parachute sonde could be expected to drift a considerable distance while descending, the tracking system would have to have an adequate range capability. The radar usually used for meteorological work (SCR 584) would have a marginal range capability without the use of a supplementary beacon of transponder on the sonde. If additional information, such as temperature, was desired, a beacon or transponder in the sonde would definitely be required.

The use of the AN/GMD-2 tracking system would require heavier and more elaborate equipment. However, there would be major advantages, the

OPERATIONAL SCHEMATIC OF ROCKETSONDE SYSTEM



most important being easier and less expensive integration of rocketsonde systems into the present continental U.S. weather network. Present plans are to adopt the AN/GMD-2 when it becomes available.

This system, presently under development, is a CW transponder system utilizing the principles of the present radiosonde with the important additional feature of supplying slant range information, thus eliminating the need for pressure measurements for determination of altitude. Slant range is computed from the phase difference between the signal transmitted from the ground station and the signal received by the ground station after having been received and retransmitted by the sonde.

Other advantages include less expensive ground equipment and greater potential for addition of meteorological sensing elements. Range limitations also are less critical with the AN/GMD-2 system.

The actual choice of a tracking and telemetering system must depend on usage. Obviously, for use on a warship where radar with adequate range is already available for search fire control purposes, a system utilizing radar would be the most practical. On the other hand, if integration with an established weather station (CONTINUED ON PAGE 44)

Synodic satellites

A consideration of the conditions under which a satellite could be established in such an orbit that it would remain in equilibrium in a constant configuration relationship with both the earth and moon

By W. B. Klemperer and E. T. Benedikt

DOUGLAS AIRCRAFT CO., INC., SANTA MONICA, CALIF.

Klemperer Benedikt

Wolfgang B. Klemperer has been with Douglas since 1936 and is now staff adviser to the chief missile engineer. Prior to joining the company, he was for 12 years manager of research in airships for Goodyear-Zeppelin Corp., and before that was with the Zeppelin Co. in Friedrichshafen, Germany. At Douglas, Dr. Klemperer initially was in charge of the development of space cabins. Later, as head of the applied physics group, he was active in design and development of the Roc family of early air-to-surface missiles. Then, as chief of the missile engineering research section, he became engaged in astronautical studies. He has also been a consultant to a number of instrument companies and to the Air Force and Navy.

Elliot T. Benedikt is now group physicist in charge of theoretical physics and applied mathematics for the Douglas missile research section. He has for more than 10 years been doing research in guidance and dynamics of long-range missiles, as well as in various fields of astronautics. Holder of a Ph.D. in physics from the University of Bologna, Italy, Dr. Benedikt has taught and conducted research at MIT, Florida U. and Rensselaer Poly, and is presently teaching the Physical Sciences Extension Div. of UCLA.

IN POPULAR speculations about lunar voyages, allusion is sometimes made to a hypothetical point, about 90 per cent of the distance from the earth to the moon, where the two opposing gravitational attractions of these bodies would balance, and above or below which the attraction of the earth or moon respectively would predominate.

This concept is, however, of no practical consequence, since the earth and moon do not stand still but revolve about a common center of gravity. Hence, any artificial satellite set up between them so as to stay in this configuration must partake of this motion and thus experience a centrifugal force which must be taken into account.

Now that artificial satellites are already circling the earth, one is tempted to formulate the query more reasonably this way:

Under what conditions would it be possible to establish an artificial (unpowered) satellite in such an orbit that it remains in equilibrium in a constant configuration relationship with the earth and moon?

Selenoid and Synodic Satellites

When the paper on which this article was based was presented at the 8th International Astronautical Congress in Barcelona last year, we referred to such satellites as "selenoid satellites." It is now proposed that the term "synodic satellites" be used for companion vehicles of any more massive two-body system, with "selenoid satellites" reserved for a companion of the moon in its trip around the earth.

It is obvious that satellites of this kind could serve as a communication network relay station for moon-earth traffic. They might also increase our knowledge of the actual mass ratio between the moon and earth—knowledge of major importance for future lunar and interplanetary navigation.

To stay in constant relative configuration with our natural moon, the artificial satellite must of course revolve in the plane and at the same lunar period as the natural moon. It is thus precisely in the condition of the restricted three-body problem which was shown by the eminent mathematician, J. L. Lagrange, 1772, to be soluble in closed form in a celebrated treatise for which the Royal

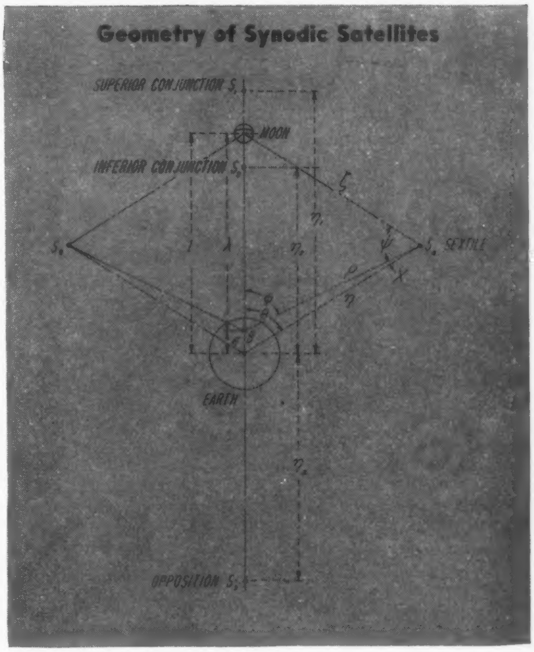
French Academy of Sciences awarded him a coveted prize.

Lagrange proved that three bodies can travel in constant constellation with respect to each other around their common barycenter, i.e., so that the ratios of their respective distances remain constant if they are situated either on a straight line or at the corners of an equilateral triangle lying in the plane of their mutual revolution. The orbits may be circular or, as would be the case with our real moon, elliptical.

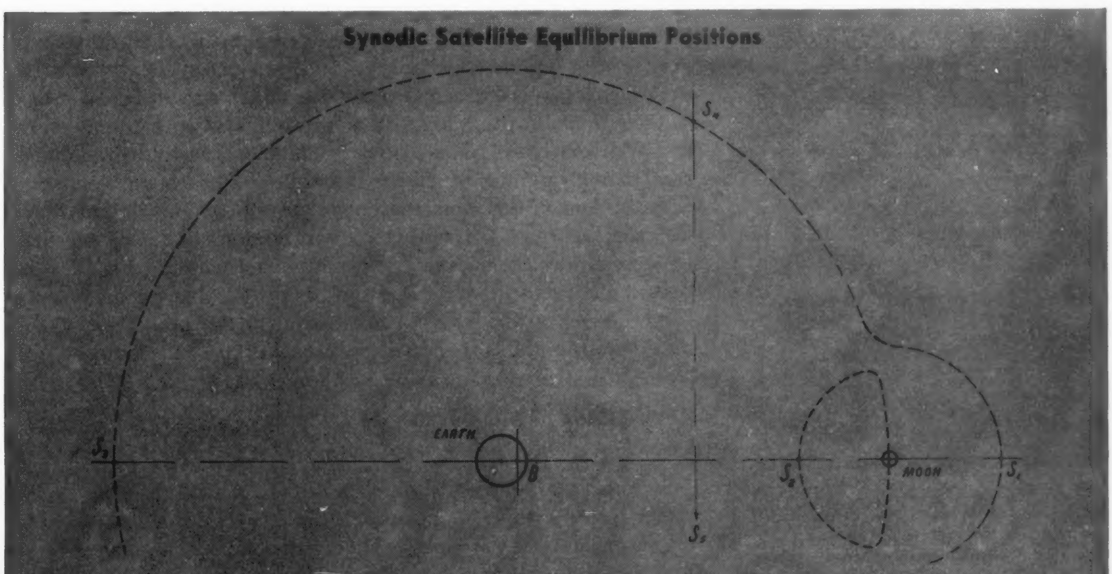
The solutions which were derived by Lagrange with great rigor and much algebra, have also been demonstrated by others, notably Laplace, Brendel, Charlier, etc.

The purpose of our present review of the problem is to look at it from a satellite navigator's viewpoint and to point out some consequences of the delicacy of the equilibrium which govern such interrelated orbital motions. For this purpose, it suffices to focus attention on the special case of circular orbits in which all distances remain constant. The extension to the slightly elliptical orbits in a real implementation is readily envisaged.

In circular motion, the radius vectors from the common barycenter to the three bodies revolve at the same constant angular (CONTINUED ON PAGE 64)



Geometry of inertial forces of earth, moon, and synodic satellite following circular motion in restricted three-body problem. Earth-moon distance is taken as unity to allow nondimensional expression of other distances.



Point	Constellation Names	η	ζ	ρ	θ
S_1	Superior Conjunction	1.1676	0.1676	1.1555	0
S_2	Inferior Conjunction	0.8490	0.1510	0.8369	0
S_3	Opposition	0.993	1.993	1.005	180°
S_4	Sextile	1.000	1.000	0.994	+60°

The points (s), their astronomical constellation names, computed coordinates as distances from earth (η), moon (ζ) and barycenter (ρ) and bearing angle from earth against moon (θ) are shown in table above.

Solids give liquids a boost

Compact and mechanically simple, solid propellant gas generators offer an alternative to high-pressure bottles or liquid propellant generators for pressurizing liquid propellant rocket motors

By Jerome Salzman

REACTION MOTORS, INC., DENVILLE, N.J.

Jerome Salzman received a B.S. in engineering from the Univ. of Michigan and did graduate work at N.Y.U. and Stevens Institute of Technology. He joined Reaction Motors in 1951 and for several years worked on jet-pump studies, boundary layer control and step-thrust rocket engines. He also did work on both solid and liquid rocket ignition and rocket motor design for missile flight control. During the past three years, he has specialized in solid propellant gas pressurization and personnel catapult projects. At present, he is charged with rocket motor testing of high-energy solid propellants.

GAS AT high pressure serves effectively to force liquid propellants from tanks into the combustion chamber of a rocket. The gas can be fed from a high-pressure bottle with valve and regulator or from a controlled chemical reaction, which conveniently takes the form of a liquid or solid propellant gas generator. Reasons can be found for employing both gas bottles and liquid propellant generators.

However, the solid propellant generator offers the advantage of simplicity, as the drawings on page 31 suggest. The solid propellant generator requires few parts or mechanical controls, and compares favorably in weight size and cost with other devices for pressurizing liquid propellants.

Germans in WW II research saw the advantage of a solid propellant gas generator, and designed an experimental anti-aircraft rocket, the TAIFUN, with concentric propellant tanks pressurized by the combustion products of a cake of cordite. For several years now, organizations in this country—among them Reaction Motors, M. W. Kellogg, and the Naval Ordnance Test Station at China Lake—have engaged in the development of liquid rocket motors with solid propellant gas generators. Necessary and desirable properties of a solid gas generator, from the standpoint of the propellant, can be set down from the cumulative experience of these programs.

Restrictions of Simplest System

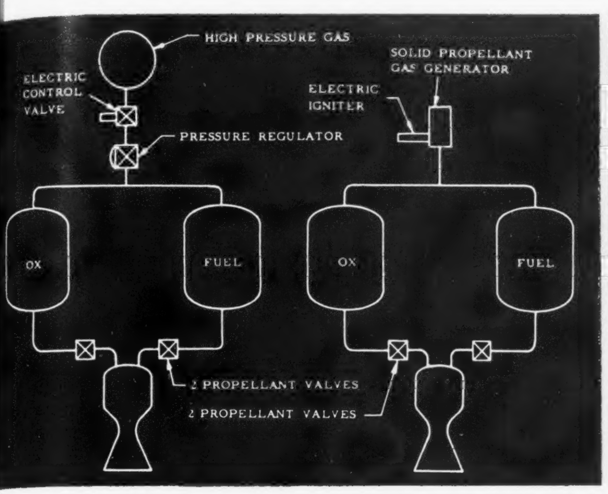
Suppose the simplest system, as shown in the drawing on the facing page: Pressurizing gas ducts directly from the generator onto the propellants in the tanks. These restrictions can at once be set for the system:

1. Any reaction between the gas and the liquid propellants must not disrupt the functioning of the rocket.

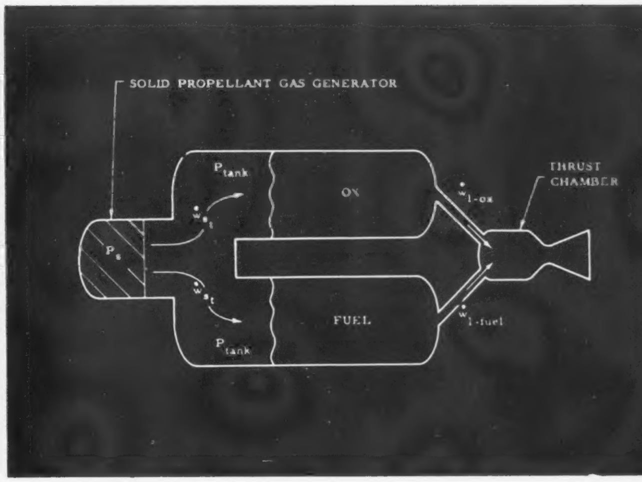
2. The gas must not erode or burn tank structure or associated parts enough to disrupt rocket functioning.

3. The gas, over a wide ambient temperature range, must deliver propellants to the combustion chamber at a rate that will maintain nearly scheduled thrust.

Simply put, the gas generator combustion products should be neutral chemically to the liquid fuel and oxidizer, so that one gener-



Diagrams of liquid motor pressurized with stored gas (left) and solid propellant gas generator (right), indicating relative simplicity of latter.



Simplest flow diagram of solid gas generator pressurizing liquid motor.

ator can be used for both. The table shown below shows the combustion products of some common solid propellants. Without exception, these propellants produce fuel-rich products with at least two reactive components.

Solid propellants with fuel-rich and oxidizer-rich combustion products can be used if they do not react violently or variably with the liquid fuel and oxidizer. The kind and degree of reaction appears from experiment to be influenced not only by gas generator combustion products but also by the temperature of the gas and liquids, the geometry and flow characteristics of the structure pressurized, the extent of the interface between gas and liquid (influenced by any churning) and even the material of tank walls.

It appears that an adequate evaluation of interaction can only be made experimentally in an actual motor system. There is urgent need, nevertheless, for solid propellants with neutral combustion products and acceptable physical and storage properties.

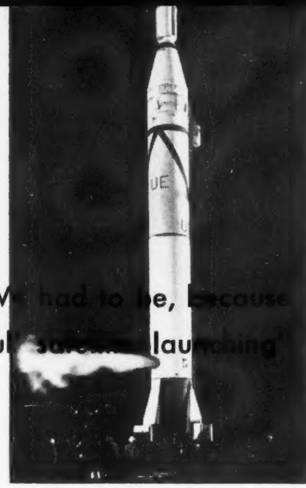
The temperature of its gaseous combustion products will also bear on the choice of a propellant. Available propellants give temperatures in the range from 800 to 5000 F. Some typical flame temperatures are shown in the table. High temperatures, as will be pointed out, keep the amount of solid propellant needed low, but they may also erode or weaken tank walls, as well as promote a gas-liquid reaction, especially with liquid monopropellants. Diffusing the gas as it enters the liquid-propellant tanks can avert focused (CONTINUED ON PAGE 78)

Thoeretical Combustion Products and Flame Temperatures of Typical Solid Propellants

Propellant	Combustion Products, volume per cent							Isobaric
	CO	H_2	H_2O	N_2	CO_2	NCl	Solids	Flame Temp, F
Double Base							‡	
OGK	43.5	24.9	12.5	9.6	9.5	—	—	2940
AGS	46.0	28.4	10.1	10.1	5.4	—	<2	1980
Composite								
Arcite 337*	6.5	77.5	9.2	2.0	0.8	3.9	<1	3250
Phillips Petroleum†	16.3	23.7	31.4	22.0	6.5	—	~1	2440

* Ammonium perchlorate base.
† Ammonium nitrate base.
‡ Trace amounts.

Rundown on Jupiter-C



'We were almost cocky about our equipment. We had to be, because we knew that there is no '98 per cent successful' satellite launching'

By Wernher von Braun

ARMY ORDNANCE MISSILE COMMAND, HUNTSVILLE, ALA.

Wernher von Braun is Director of ABMA's Development Operations Div., which has technical responsibility for the Redstone, Jupiter and Pershing missiles and Jupiter-C as a re-entry test vehicle and Jupiter and Jupiter-C as satellite-launching rockets. Born in Wirsitz, Germany, in 1912, he received a Ph.D. in physics from the University of Berlin in 1934. As an undergraduate there he joined the German equivalent of the American Rocket Society, *Verein fur Raumschiffahrt*. Dr. von Braun contributed prominently to the design and development of the V-2, and became technical director of Peenemuende in 1937. Coming to this country under contract with the Army at the close of WW II, he worked on high-altitude V-2 firings at White Sands, was project director of a guided missile development unit at Fort Bliss, Tex., and then assumed his present position at Redstone when it was made an Army development center for rockets and missiles. Dr. von Braun's many honors include the ARS Astronautics Award in 1955 and a Distinguished Civilian Service Award in 1957. He is on the ARS Board of Directors and is a member of the ARS Space Flight Committee.

I WANT to describe for you some facets of Jupiter-C, the rocket which I am very fond of that put our first satellite into orbit, and give you some sidelights on the launching of Explorer I. I am not going to describe the satellite payload itself, because you already have an excellent description of it prepared especially by JPL for the April, 1958 issue of ASTRONAUTICS.

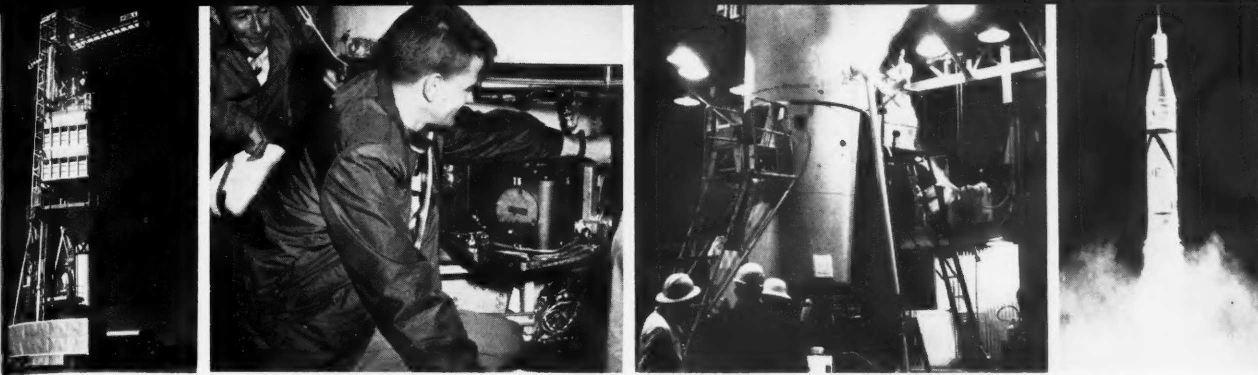
In the four-stage Jupiter-C, the engine of the Redstone missile, modified to take longer propellant tanks, forms the first stage. Bigger tanks were possible because the upper stages of Jupiter-C, which we will come to in a moment, weighed substantially less than Redstone's heavy warhead. At the suggestion of Rocketdyne, our powerplant contractor, we substituted for the alcohol normally used in Redstone a fuel that gave roughly 15 per cent higher specific impulse with lox, yet did not require any major hardware changes.

The greater energy of this fuel and the increased tankage allowed us both to boost thrust from the Redstone's nominal 75,000 lb to 83,000 lb and to extend burning time from 121 to 155 sec. The extended burning time necessitated adding another hydrogen peroxide tank to the engine to keep the turbo-pump running.

On top of the tank section of the first stage sits the compartment that houses guidance and control equipment for the first stage and a "spatial-attitude control system" that aligns this section and the forward stages horizontally at the apex of the first stage's trajectory. One of the photos on page 33 shows this instrument compartment sitting in our flight-checkout and assembly hangar at Canaveral. The dark stripes on the cylindrical part of the compartment are antennas—one for telemetering, one for Doppler tracking and one for radio command. The little balconies at the bottom house air nozzles linked to the spatial-attitude control system. I'll have more to say about these nozzles in a moment.

Although you can't see them in the photo, there are six explosive bolts, each surrounded by a preloaded coil spring, equispaced around the base of the compartment to join it and the other stages to the booster. Tiny powder charges in the bolts are set off to sever the bolts and free the springs, which impart a velocity increase of only 2.6 fps to the compartment and forward stages. Quick-disconnect couplings free the many cables and tubes running between the compartment and the first-stage booster.

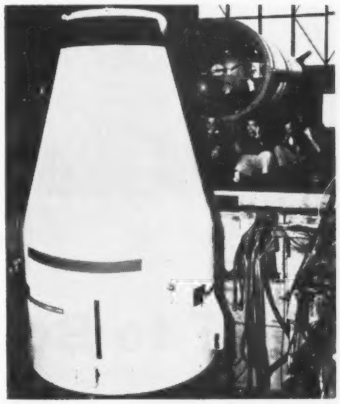
The instrument compartment has no doors or access hatches, and it was necessary to lift its entire cover to work on equipment inside. This would be intolerable in a military missile, where ease of hand-



Preparations and launching. At left, Jupiter-C, fully assembled, awaits countdown while wrapped in protective embrace of giant gantry. Next, technicians check gyro assembly for booster control, and load lox and hydrogen peroxide. And, finally, missile away!

ling and accessibility are of great importance. However, it was not too awkward with this research rocket and it saved precious pounds in constructing the compartment.

The photo at right, taken during a test of the instrument compartment, shows the compartment bolted to a rocking table at the bottom of a 10-ft-deep pit. The table, gimbal-suspended and driven by three electric motors, can be rotated and also rocked back and forth in two planes. The gyros run during this kind of test, and potentiometers pick up any error angles developing between the stable gyro reference and the rocking compartment and inject the deflection signals into the control loop.

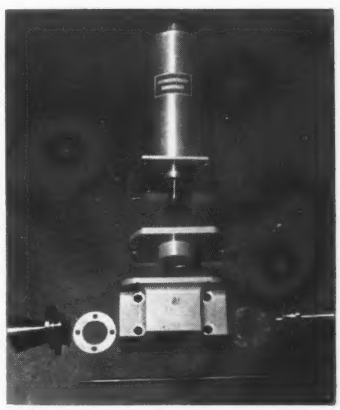


Instrument compartment, housing guidance and control equipment and spatial-attitude control section, sits on test table in Canaveral checkout and assembly hangar.

Depending on whether the test is concerned with control of the booster during the first stage of flight or checking of the spatial-attitude control system and air nozzles, you get a direct response of the jet vanes on the booster or air nozzles on the instrument compartment. You can see directly, for example, if the nozzles have the correct flow rate, if a control needle is sticky, the polarity right, etc. We do this kind of "rocket-and-roll" testing with all our instrument compartments, and find it a very convenient and reliable method for checking the entire control system in all its functions.

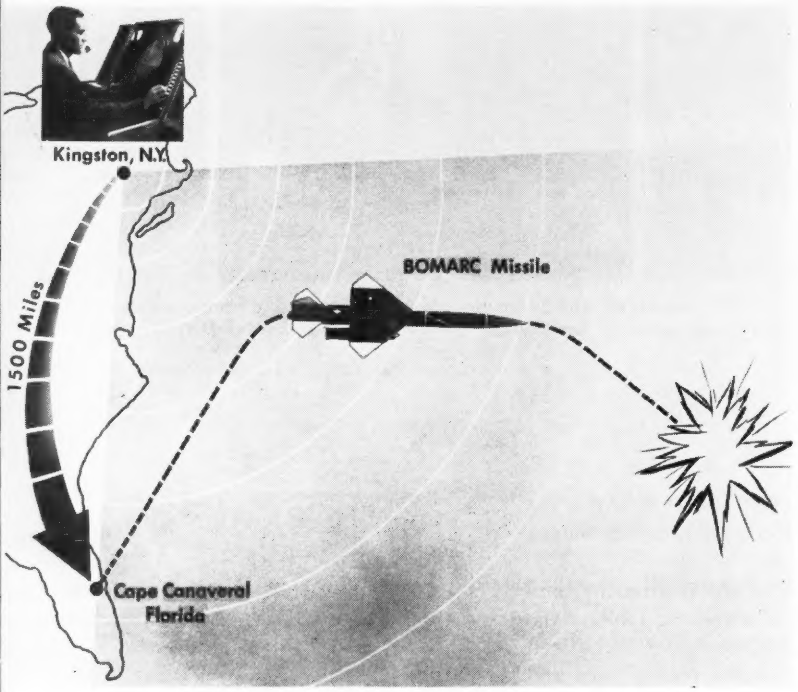
Air Nozzles Align High-Speed Stages

As I have mentioned, the instrument compartment and forward stages, after separation from the booster and during ascent to the apex, must be exactly aligned horizontally with the surface of the earth directly beneath. The air nozzles of the spatial-attitude control system bring about this alignment. The photo to the right shows one of the four pair of nozzles in exploded view. A nozzle unit can deliver a maximum thrust, left or right, of 5 lb.



Exploded view of one of four pair of air-jet nozzles used to control attitude of the instrument compartment and upper stages in ascent to apex.

A small electric motor drives a sprocket wheel to control air flow. The cogs of this wheel engage the teeth of a push-pull needle, which appears at the bottom of the photo. As the needle, driven by the motor, moves to the right or left, more or less air enters either nozzle. The smooth movements of the needle thus give a "proportional control" system much more refined than the "bang-bang" system used in the top section of Redstone. The nozzle system showed an accuracy of $^{1}/_{10}$ deg in rocking and other analog tests. The need for this accuracy will become apparent (CONTINUED ON PAGE 80)



Weapon director in practice SAGE control center in Kingston, N. Y., pressed button to send Bomarc missile, 1500 miles away at Canaveral, streaking to intercept target drone.

SAGE to Bomarc to target

ONE OF the gaps in our continental air defense came near closing with the recent direction of a Cape Canaveral-launched IM-99 Bomarc from a practice SAGE center in Kingston, N.Y., some 1500 miles away. For the first time, the "brain" of the SAGE system, the computer, followed the tracking of a realistic target (high-speed drone), determined intercept point and directed Bomarc to the target.

This exercise brought together formally the country's main air-defense network (May, 1958, ASTRONAUTICS, page 42) and longest-range ground-to-air missile. Bomarc is a rocket-boosted, ramjet-powered missile with an operational radius of 250 miles against aircraft and air-breathing missiles. Radio signals from a ground station guide Bomarc to the area of intercept, where its own guidance picks up the target and directs the attack home.

SAGE transforms data from radar tracking of the target to commands that will guide Bomarc to the intercept area. The computer at the SAGE control center links with tracking radar by a special telephone line; another line links the computer to the ground-station radio command to Bomarc. Without the intervention of an operator, then, the computer can communicate directly with tracking and command sections of the ground station, the language for this hookup being a mutually usable code. A weapon director at the SAGE center, of course, commits a Bomarc to an attack—with the permission of the computer, which, during the tracking of the target, gives the weapon director "Yes" or "No" answers to the question: Can the target be attacked with assurance of interception?

The computer (IBM's AN FSQ-7, XD-2) used at Kingston was one of the first completed for the SAGE system. It employed an interim card program prepared by IBM with the assistance of Boeing, developer and builder of the Bomarc weapon system, and Lincoln Laboratories, developer of SAGE. Systems Development Corp. is designing a card program for service use of Bomarc with SAGE.

In normal Bomarc-SAGE operations, a control station will not have to extend its command even half the 1500 miles used in this first exercise. In the near future, a SAGE center at Montgomery, Ala., will command Bomarcs emplaced at Eglin Air Force Base, Fla. When centers like Montgomery go into service, the U.S., after a decade of planning, will finally have the capability for long-range interception of enemy aircraft and missiles.

ASTRONAUTICS Report—Part Two

Instrumentation for large-scale captive missile tests

A recently completed system strikes a balance among design goals of large data capacity, high-speed automatic operation, fast data reduction, accuracy, and reliability

By R. A. Ackley

CONVAIR-ASTRONAUTICS, A DIVISION OF GENERAL DYNAMICS CORP., SAN DIEGO, CALIF.

HAVING established some criteria for the instrumentation and data-processing systems used in large-scale captive missile tests, let us now turn our attention to an instrumentation system for such testing that was recently put into operation at Convair. This system pushed the state of the art in the areas of automatic functioning and FM signal transfer.

Let's begin with the data-processing station, because the criteria on which it was based came primarily from the requirements of processing flight-test data, and the rest of the system was designed to match it.

An FM/FM telemetering system was chosen for flight testing for four chief reasons: Need for many continuous channels for stability studies and environmental information; amenability to automatic data-processing methods; availability of off-the-shelf components; and existence of ground receiving and recording stations. This choice dictated processing-station input and capacity.

A schematic diagram of the station, which will accept either 7- or 14-track magnetic tape, is shown on page 36. The FM data signal from the playback is discriminated to produce analog voltages feeding to computers, analog recorders or analog-to-digital converters, the latter leading to tabulators or tape recorders. Any data signal can be sent through either digital or analog computers before recording or printing.

Plots Arc in Units of Quantity Measured

Zero-offset and scaling amplifiers of the recording system permit adjustment to produce plots directly in units of the measured physical quantity. There is no provision for automatic linearity correction. Where high accuracy indicates a need for such correction, it is handled as a special case in a computer. The high-speed digital printer can print 30 lines of 120 decimal digits a second. A digital memory for zero-offset and scale factor makes possible printing in units of measurement.

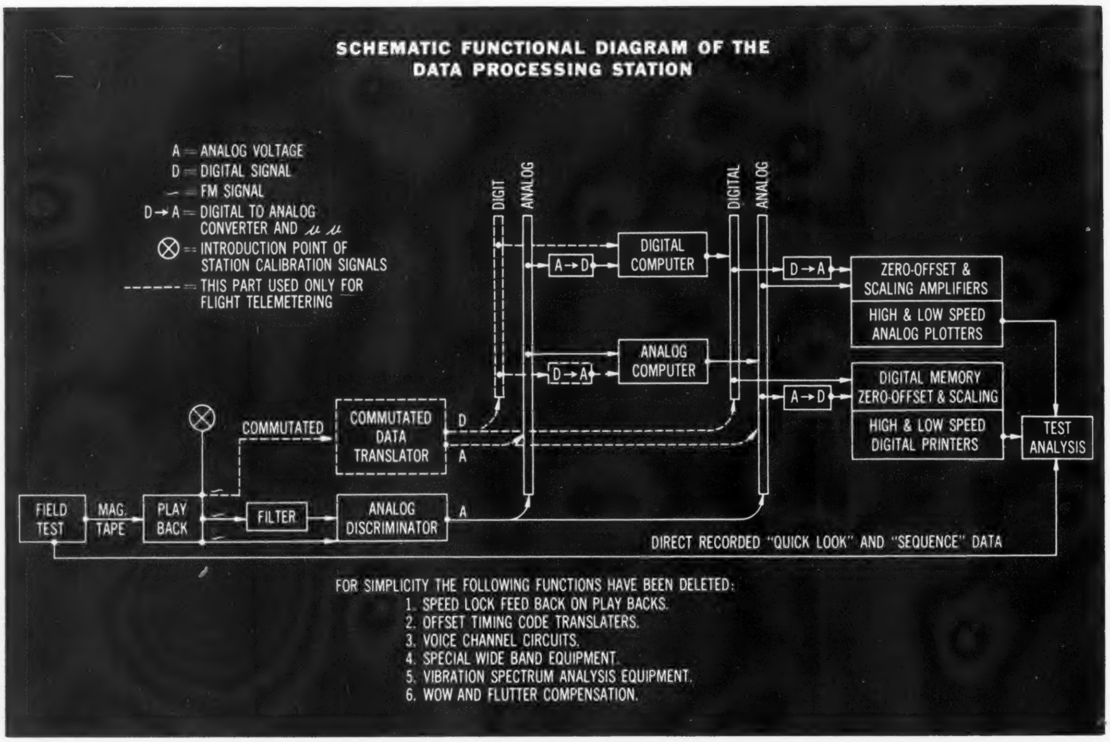
Not shown on the diagram are the time-offset timing-code translators. These permit conversion of real time, as recorded on the test tapes, to any new time reference base. For instance, zero time

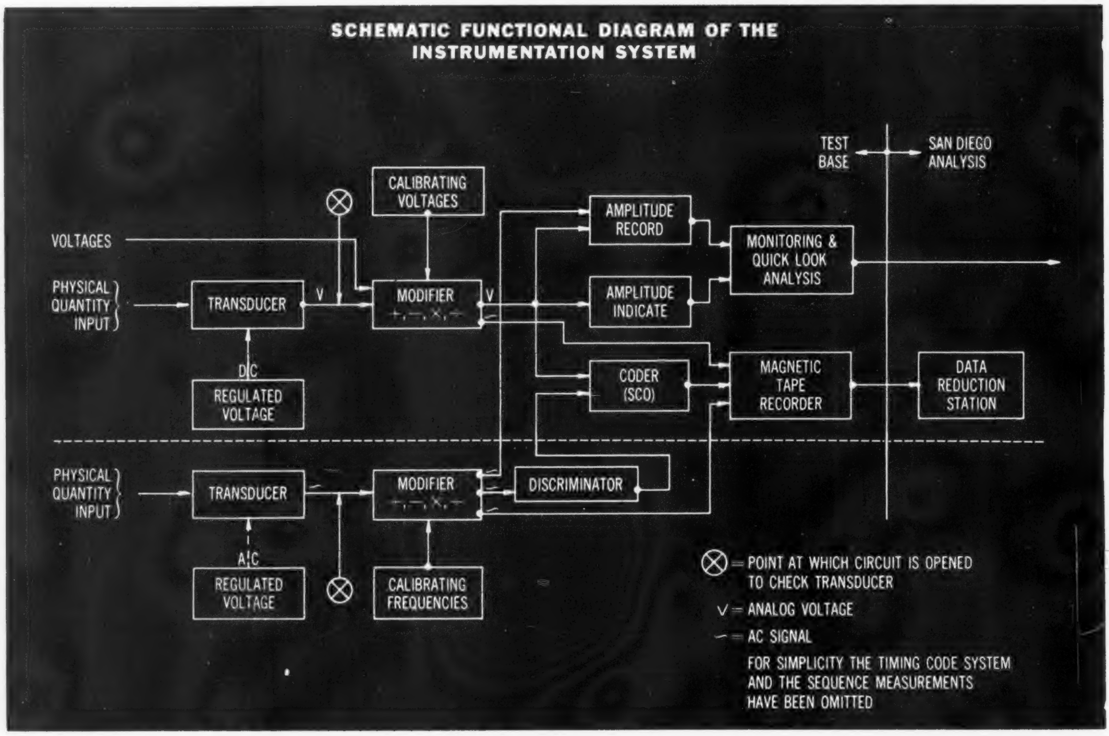
BACKGROUND

In a previous article in the Instrumentation and Guidance Number of ASTRONAUTICS (May, page 48), the author described the effects on missile testing of broad policy, planning, measurement selection, and design-change control. These considerations resulted in the establishment of some basic criteria for the instrumentation and data-processing systems used for captive testing of large missiles.

Among these criteria are minimum setup and checkout time; minimum data-processing time to produce corrected data; establishment of monitoring and "quick look" data requirements; flexibility; and, of course, reliability and accuracy.

This article takes a closer look at the instrumentation system itself and describes how the system operates in obtaining necessary test data.


SCHEMATIC FUNCTIONAL DIAGRAM OF THE DATA PROCESSING STATION
A = ANALOG VOLTAGE
D = DIGITAL SIGNAL
= FM SIGNAL
D→A = DIGITAL TO ANALOG CONVERTER AND
⊗ = INTRODUCTION POINT OF STATION CALIBRATION SIGNALS
------ = THIS PART USED ONLY FOR FLIGHT TELEMETERING
DIGIT
ANALOG
DIGITAL
ANALOG
DIGITAL COMPUTER
ANALOG COMPUTER
A→D
D→A
ZERO-OFFSET & SCALING AMPLIFIERS
HIGH & LOW SPEED ANALOG PLOTTERS
DIGITAL MEMORY ZERO-OFFSET & SCALING
HIGH & LOW SPEED DIGITAL PRINTERS
TEST ANALYSIS
COMMUTATED
COMMUTATED DATA TRANSLATOR
FIELD TEST
MAG. TAPE
PLAY BACK
FILTER
ANALOG DISCRIMINATOR
DIRECT RECORDED "QUICK LOOK" AND "SEQUENCE" DATA
FOR SIMPLICITY THE FOLLOWING FUNCTIONS HAVE BEEN DELETED:
1. SPEED LOCK FEED BACK ON PLAY BACKS.
2. OFFSET TIMING CODE TRANSLATERS.
3. VOICE CHANNEL CIRCUITS.
4. SPECIAL WIDE BAND EQUIPMENT.
5. VIBRATION SPECTRUM ANALYSIS EQUIPMENT.
6. WOW AND FLUTTER COMPENSATION.


SCHEMATIC FUNCTIONAL DIAGRAM OF THE INSTRUMENTATION SYSTEM
TEST BASE
SAN DIEGO ANALYSIS
CALIBRATING VOLTAGES
VOLTAGES
PHYSICAL QUANTITY INPUT
TRANSDUCER
MODIFIER +, −, ×, ÷
DC
REGULATED VOLTAGE
AMPLITUDE RECORD
AMPLITUDE INDICATE
MONITORING & QUICK LOOK ANALYSIS
CODER (SCO)
MAGNETIC TAPE RECORDER
DATA REDUCTION STATION
DISCRIMINATOR
AC
CALIBRATING FREQUENCIES
⊗ = POINT AT WHICH CIRCUIT IS OPENED TO CHECK TRANSDUCER
V = ANALOG VOLTAGE
= AC SIGNAL
FOR SIMPLICITY THE TIMING CODE SYSTEM AND THE SEQUENCE MEASUREMENTS HAVE BEEN OMITTED

may be made the instant of liftoff during a launching, and then applied to all data produced.

These four features—time offset, high-speed printer, commutated-data translator and scaling ampifiers—are considered a distinct advance in the state of the art.

Space does not permit describing in detail the checkout and calibration features and procedures that give automatic correction for such things as wow and flutter, zero and sensitivity drift in subcarrier oscillators and discriminators, and drift in transducer power supplies.

For captive-test purposes where commutation is not used, the station can process 12 data channels to correctly scaled analog plots and one channel to digital print-out in 30 minutes, including setup and running time. To this must be added processing time for any oscillograph paper and some additional time for identifying and marking scales.

First Data Unscaled

Generally, data is processed first without scaling, which takes one or two hours. The first data through the mill serves for "quick-look" troubleshooting and determining the best scale factor for final processing, which takes an additional eight to 10 hours.

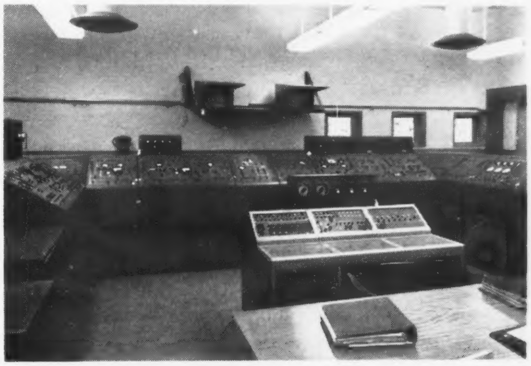
The "land-line" captive-test instrumentation system developed to go with this data-processing station is an adaptation of the flight telemetering system.

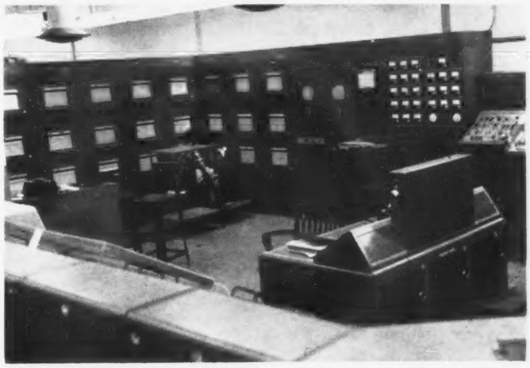
A schematic functional block diagram of the system is shown on page 36. Considering, first, the part above the horizontal dotted line, the physical quantity to be measured enters on the left and, if already a voltage, goes directly to the signal modifying unit (SMU). Otherwise, it is transformed by the transducer into a voltage and then goes to the SMU. From the SMU, the modified signal goes to the coder—in this case, subcarrier oscillators (SCO's) frequency-modulated in proportion to the signal. Six of these frequencies are then combined with a 100-kc reference signal and recorded on one track of the magnetic tape.

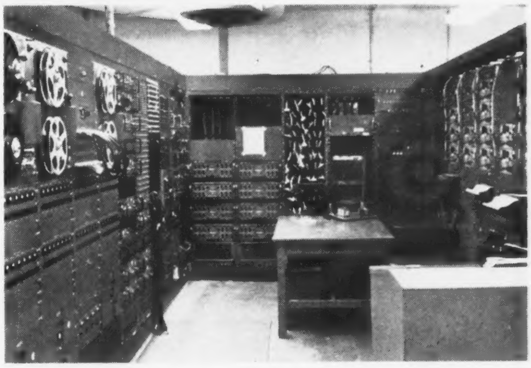
Converting the signal from amplitude to time (frequency) intelligence has the general advantage of minimizing the effects of variable attenuation in transmission and environmental effects on the tape storage system. Modulating frequency is only one of several ways of doing this. Pulse duration or pulse-width and digital coding are also in common use. In general, the FM system is better for transient data, while the others are more accurate for steady-state data.

The frequency bands are the same as those used in FM telemetering except that on land-line measurements only every other band is used. We use 11 of the 14 tracks available on the 1-in. tape in this way. The remaining three carry time, voice, and "garbage." The garbage track contains, among other things, command signals used by the data processing station in the automatic calibration process.

The 100-kc signal is used for speed lock of playback and for electronic wow and flutter compensation in the processing station. A typical captive test installation will contain two such recorders, giving an FM data capacity of (CONTINUED ON PAGE 58)







The control center of the instrumentation system includes these key areas—main control consoles (top), "quick-look" stage (center), and FM recording bay (bottom).

Auguries of space flight, U.S.A.

THOMAS KEITH GLENNAN was appointed director of the National Aeronautics and Space Administration (NASA), and Hugh Dryden, head of the National Advisory Committee for Aeronautics, was appointed deputy director. Glennan will leave his present job as president of Case Institute of Technology, Feb. 1, 1959, to devote full time to the work of the new Agency, which he will serve four days a week until that time.

T. Keith Glennan graduated from Yale University with a B.S. in electrical engineering in 1927. Early in his career, he installed motion picture sound equipment; and he managed studios for Paramount Pictures and Goldwyn Studios from 1935 to 1941. Although briefly an executive with Vega Aircraft Corp. thereafter, during most of WW II he directed the Navy's underwater sound laboratory at New London, Conn., receiving the Legion of Merit for his part in the development of submarine detection devices there. He became manager of administrative services for the Ansco Division of General Aniline and Film Corp. after the war. In 1947 he became president of Case.

President Eisenhower hands commissions to Thomas Keith Glennan as director of NASA and Hugh L. Dryden as deputy director in dual White House ceremony August 19.

From 1950 through 1952, Glennan was a member of the Atomic Energy Commission (AEC). He is now a member of the board of the National Science Foundation, chairman of the board of the Institute for Defense Analysis, member of the board of the Council on Financial Aid to Education, and a members, chiefly chairman McCormack, for suggesting

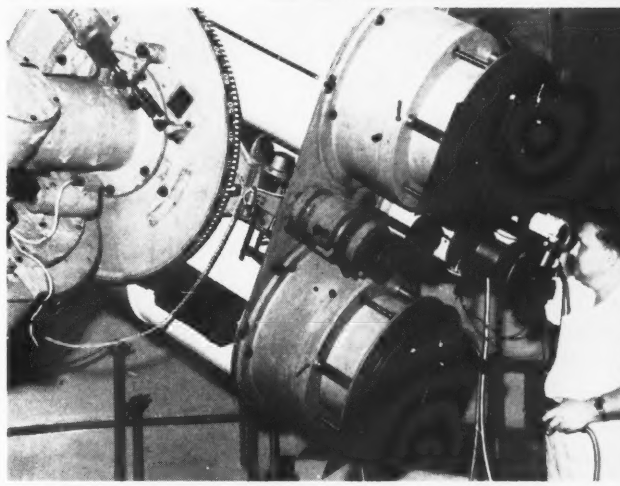
Glennan considers himself an applied scientist. When queried what his chief concern would be as head of NASA, he replied, "To administer the Act." Testifying before the Senate Space Committee during the hearings for his nomination to head NASA, Glennan declined to say whether funding for NASA appeared adequate for peak operation, but he underscored the need to expand NASA beyond the form of NACA.

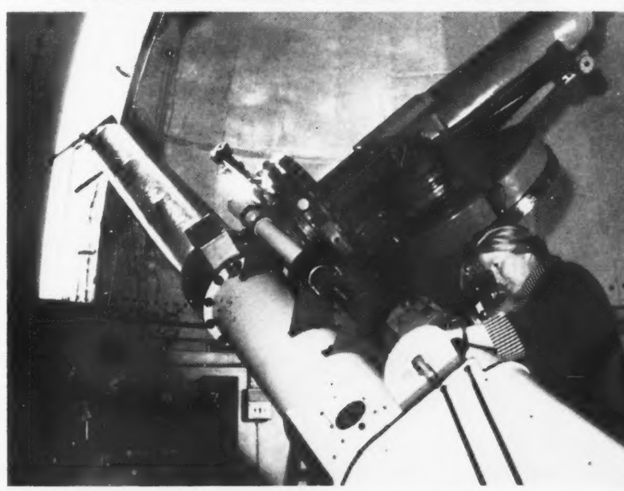
Dryden Gave Views

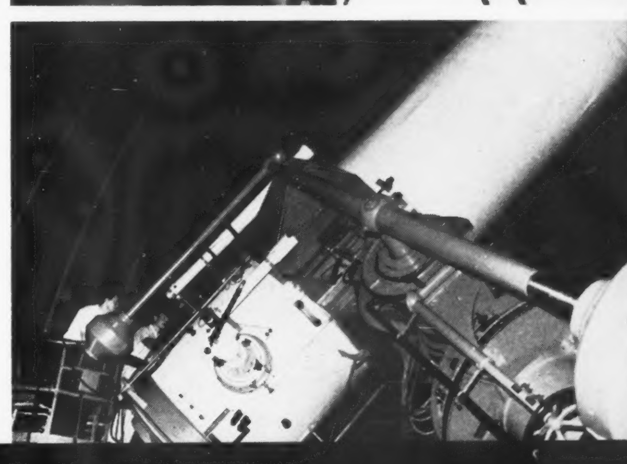
Dr. Dryden should need no introduction now. His views on the course of national planning for space flight have been much publicized. Just before the nomination of Glennan, Dryden took a verbal pasting from House Space Committee members, chiefly chairman McCormack, for suggesting he would not be able to use more direct funds than the $125 million proposed by the Senate. He also has shied at the suggestion atomic power will open the age of space flight. Money and atomic power (i.e., more energy to match imagination) mark the standard of those who aim seriously at taking man into the reaches of space.

Dryden, if not Glennan, lives with irony. During his testimony before the House Space Committee, it appeared the legislators would like to give NASA more money than requested for it. But House-Senate conferees on the NASA budget cut $45 million from the $125 million requested—slashing salaries and expenses from $7 to $5 million, research and development from $70.2 to $50 million, and construction and equipment from $47.8 to $25 million. Supplementing this direct $80 million appropriation for NASA's first year will be $117 million transferred from DOD and $101 million already appropriated for NACA (and probably already committed on old projects). These funds total $298 million. By coincidence, DOD's Advanced Research Projects Agency (ARPA) will get close to $300 million, and it need not support (CONTINUED ON PAGE 88)

These Russian photos show some of the Observatory buildings and equipment. Top to bottom, the towers of the Astrophysics Dept.; the "double astrograph" (probably the telescope with dual cameras referred to in the text) used for tracking Sputniks; the coronograph; and the spectrograph of the 122-cm reflecting telescope.







Russian eye on space

From the Crimean Astrophysical Observatory, Soviet scientists view the heavens, track Sputniks and participate in other IGY activities

By Pyotr Dobronravin

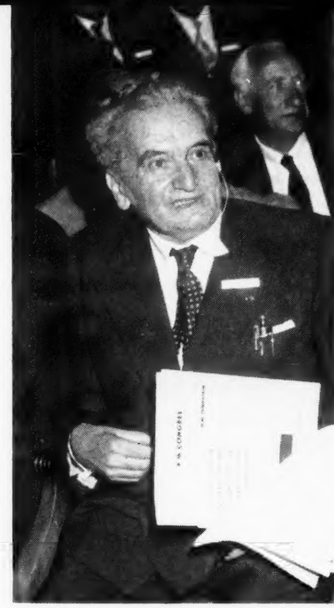
DEPUTY DIRECTOR, CRIMEAN ASTROPHYSICAL OBSERVATORY

IN THE central part of the Crimean Peninsula, at a site 600 m above sea level, stands the Crimean Astrophysical Observatory of the U.S.S.R. Academy of Sciences, the main astrophysical observatory in the Soviet Union. The Observatory is taking an active part in the International Geophysical Year, having broadened for that purpose its programs of sun study and associated terrestrial phenomena, such as changes in the ionosphere and the earth's magnetic field, and having installed a tracking station with cameras to follow and record the paths of the Sputniks.

Before telling you briefly of our work, let me mention that, although the Observatory, as an institution, has functioned for over half a century, it and its instruments, at the time located in Simeiz, were wrecked during WW II, and had to be rebuilt and re-equipped. This work was finished at the present site in 1955.

In our regular research program, we study the physics of the sun, the stars and gaseous nebulae. The Observatory has a coronograph and one of the largest tower telescopes in the world for solar observation. The telescope can give a sun image up to 35 cm in diam and has a spectrographic range of 30 m. Three small telescopes, receptive to different wavelengths, record radio waves emitted by the sun.

The Observatory also (CONTINUED ON PAGE 84)



Theodore von Kármán awaits opening of the 9th IAF Congress in Amsterdam.

The Amsterdam IAF Congress

Peaceful talk of space

By Irwin Hersey

AMSTERDAM, THE NETHERLANDS—The Ninth Annual Congress of the International Astronautical Federation, held here Aug. 25–30, not only attracted the largest attendance in IAF history, but also produced more than 70 technical papers by scientists and engineers from 14 countries, a spirited contest for the IAF presidency and what may well be the most significant step taken to date toward international astronautical cooperation.

The conference drew a turnout of more than 400 from some 35 countries, including a large U.S. delegation headed by Kurt Stehling of NRL and including such luminaries as USNC-IGY Chairman Joseph Kaplan; Richard W. Porter, Chairman of the U.S. IGY Earth Satellite Panel; ARPA Chief Scientist Herbert York; Fred L. Whipple, Director of the Smithsonian Observatory; Wernher von Braun of ABMA; Homer Joe Stewart of JPL; and many others. The Russians seated an eight-man delegation headed by Academicians L. I. Sedov, an IAF vice-president, and K. F. Ogorodnikov.

The contest for the presidency grew out of a decision taken several years ago by IAF against allowing a president to succeed himself. Bearing this fact in mind, the Nominations Committee, headed by Dr. Sedov, went on record as favoring election of a noted scientist to head the IAF in the future. However, Ogorodnikov, speaking for Sedov, read a letter from the Polish delegation urging the committee to consider renominating Andrew G. Haley. The Committee first selected J. Ackeret of the Federal Institute of Technology, Geneva, Switzerland, for the presidency. When Dr. Ackeret declined the nomination, the committee selected L. R. Shepherd of England.

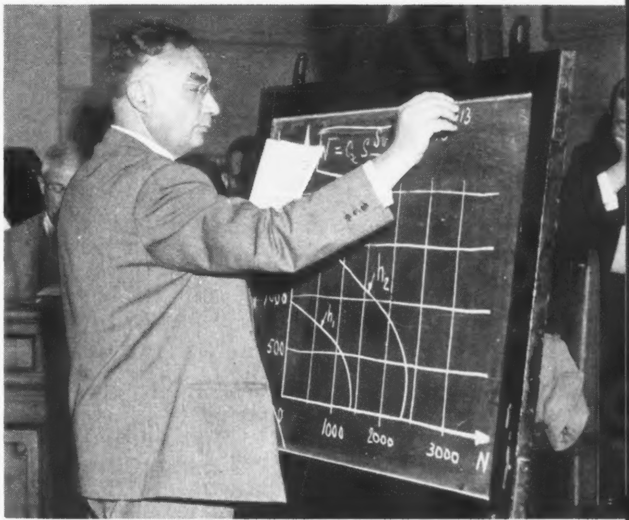
However, Haley, who himself spoke in favor of Dr. Shepherd's election, was nominated from the floor by the German delegation, headed by Eugen

Academician L. I. Sedov, IAF vice-president (center), discusses a point with another member of the Russian delegation.

Sänger, and seconded by the Argentine delegation, which demanded a secret ballot. Haley was re-elected by a close 11–9 vote.

Sedov, Shepherd and Sanger, T. M. Tabanera of Argentina, Paul Bergeron of France and K. Zarankiewiez of Poland were elected vice-presidents, while Josef Stemmer was re-elected secretary.

The 1959 Congress will be held in London the second week in September, with the British Interplanetary Society as host.



Dr. Sedov jots down a formula during presentation of his paper.

Colloquium on Space Law Held

One of the highlights of the conference was the colloquium on "The Law of Outer Space," held at The Hague, with Haley as chairman. Fifteen countries participated in the colloquium, which approved a resolution, later passed by the congress, calling for the settling of legal problems in astronautics by a new international convention and creation of a permanent IAF Space Law Committee. The resolution reads as follows:

(1) That the legal problems created by the development of astronautics be settled through a new international convention; (2) that within the framework of the Federation there be created a permanent legal committee open to lawyers of the various societies or groups affiliated to the Federation, and whose members be intrusted with the study of all the problems of the law of space to be included in the convention mentioned in resolution 1; (3) that the above resolutions be communicated to the Secretary General of the United Nations, who should be assured of the desire of the Federation to cooperate in any initiative to be taken in the field of astronautics by the United Nations.

Scene at one of the plenary sessions. Former IAF president Fred Durant of U. S. delegation is at left foreground.

Another of the important steps taken at the Congress was unanimous approval by the delegates of a four-point program which may help pave the way for international cooperation in future astronautical projects. Drawn up by the International Affairs Committee, headed by former IAF President Fred Durant of Avco, the program calls for:

1. Collection and dissemination from one focal point of information on plans and progress of space flight research activities of all nations.
2. Establishment of international space flight research fellowships in astronautical subjects.
3. Setting up an international competition for selection of research experiments for satellite vehicles.
4. Holding an international conference on the subject of peaceful applications of rockets and satellite vehicles.

IAF wheels. Left to right: L. R. Shepherd of Great Britain, vice-president; Andrew G. Haley, president; and Josef A. Stemmer of Switzerland, secretary.

According to Durant, steps will be taken to implement the program during the coming year. One of the Russian delegates (CONTINUED ON PAGE 90)

Russian Light on Cosmonautics

The year 1958 began on Soviet calendars as the second year of cosmonautics, while we yet awaited the launching of a U. S. satellite and most of us wondered just what program the Russians had developed for the conquest of space. Sputnik II assured the technically literate community that the Soviet satellite program indeed represented solid achievements in propulsion, guidance and instrumentation, and that the initial success of the Sputniks would be sustained in coming years. The Soviet program for IGY showed conclusively the thoroughness of Russian thinking and planning for flight throughout the earth's atmosphere, a necessary concomitant to manned earth satellites.

This program outlined study of atmospheric structure and optical properties, ultraviolet and X-ray radiation from the sun, corpuscular radiation of sun and aurora, cosmic ray and ionospheric phenomena, the earth's magnetic field, micrometeorites and meteoroids and physicochemical processes in the upper atmosphere. It announced that 125 sounding rockets would be launched for the IGY, as a continuation of the Soviet program for high-altitude research begun in 1949. The Soviet Union sent a sounding rocket to a record height of 473 km Feb. 21 and launched Sputnik III May 25, giving witness to their ability to carry out immediately these plans for systematic exploration of the atmosphere and its border in space.

Meanwhile, as 1958 progressed into summer, the Soviet Union still withheld most concrete information on the Sputniks, sounding rockets and data taken with them.

Report on Sputniks

This silence ended to some extent at the Fifth Assembly of the IGY Governing Body, which convened in Moscow the last week in July. There Western scientists received the first substantial Russian report on data taken with the Sputniks. The highlight of the Fifth Assembly was an illustrated talk by Prof. Sergei N. Vernov on Soviet cosmic ray studies with satellites and sounding rockets. Prof. Vernov confirmed U. S. findings with the Explorers that at least part of the earth is covered by a deep layer of powerful radiation and that the intensity of the radiation varies with altitude. Vernov implied that Sputnik II picked up evidence of this radiation last Nov. He offered tentative explanation of the radiation along lines advanced here, that the layer may be caused by streams of ionized gas proceeding from the sun or more distant bodies and held by the earth's magnetic field, and alternatively, that the radiation might be electrons produced by splitting of cosmic ray particles.

The use of Sputnik II to study radiation is also suggested by the announcement a month earlier in the Soviet press that the first months of IGY discovered new knowledge of geomagnetism. The structure of the earth's magnetic field in the upper layers of the atmosphere did not coincide, as previously thought, with lines of equal intensity of radiation. The Russians charted the distribution of "cosmic" radiation in longitude and latitude by aircraft, and confirmed the discrepancy in fields with "the very first results of cosmic-radiation observations with a sputnik."

The Fifth Assembly did seem to mark a break in Soviet reticence; and observers felt the Fifth Assembly would be followed by increasing Russian contributions to IGY.

Moreover, prominent Russian scientists have continued to comment openly on major technological problems of space flight. P. Isakov, a Stalin Prize winner for his role in Sputnik II (see Feb. 1958 Astronautics, p. 38), commenting on hermetically sealed capsules and ejection apparatus for satellites, gives protection of crews from temperatures over 100 C, from prolonged deceleration at 3–5 g, and from rapid and irregular rotations as key re-entry problems yet to be solved.

Isakov also refers vaguely to a number of problems no less important, obliquely citing the difficulty of picking the right spots for firing retrorockets to slow a satellite and for ejecting a capsule. The Russians show some weakness in predicting orbits (computing), tracking, and telemetry. At the Fifth Assembly, they evinced special interest in the equations for predicting satellite orbits developed by R. Jastrow of the Naval Research Lab; and they have been setting up more and and better optical tracking stations, for instance, the new station at the Main Astronomical Observatory of the Academy of Sciences in Kiev for optical tracking and photographic recording of Sputnik III.

Ambitious and Practical

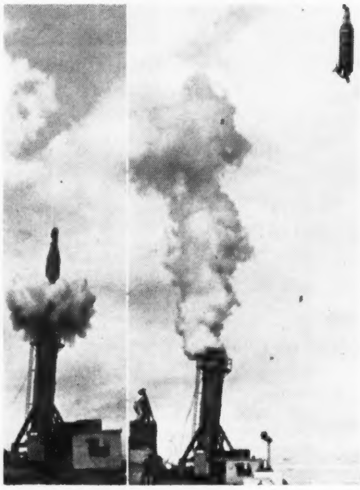
Views expressed by Prof. G. V. Petrovich, writing in the official organ of the U.S.S.R. Academy of Sciences, suggest the ambitious yet practical attitude of Russians toward space flight, and again point to their technical strengths and possible weaknesses.

Petrovich sees, at least for the immediate future, all practical problems of cosmonautics (as the Russians refer to space flight) being solved on the basis of chemical rocket engines that have been scrupulously planned, tested and developed in every detail. His emphasis on development and testing indicates the Russians too learned reliability the hard way. He expects large manned satellites that can be oriented in space will be put into orbit in the next few years, with return to earth by glider. And he emphasizes the need to develop methods of computing trajectories and to run trajectory calculations on electronic computers. Finally, Prof. Petrovich underscores the *historical* significance of the first flight by a rocket to the moon, and adds that the Russians have determined performance for a lunar vehicle, and that we may expect a series (sic) of Russian lunar rockets.

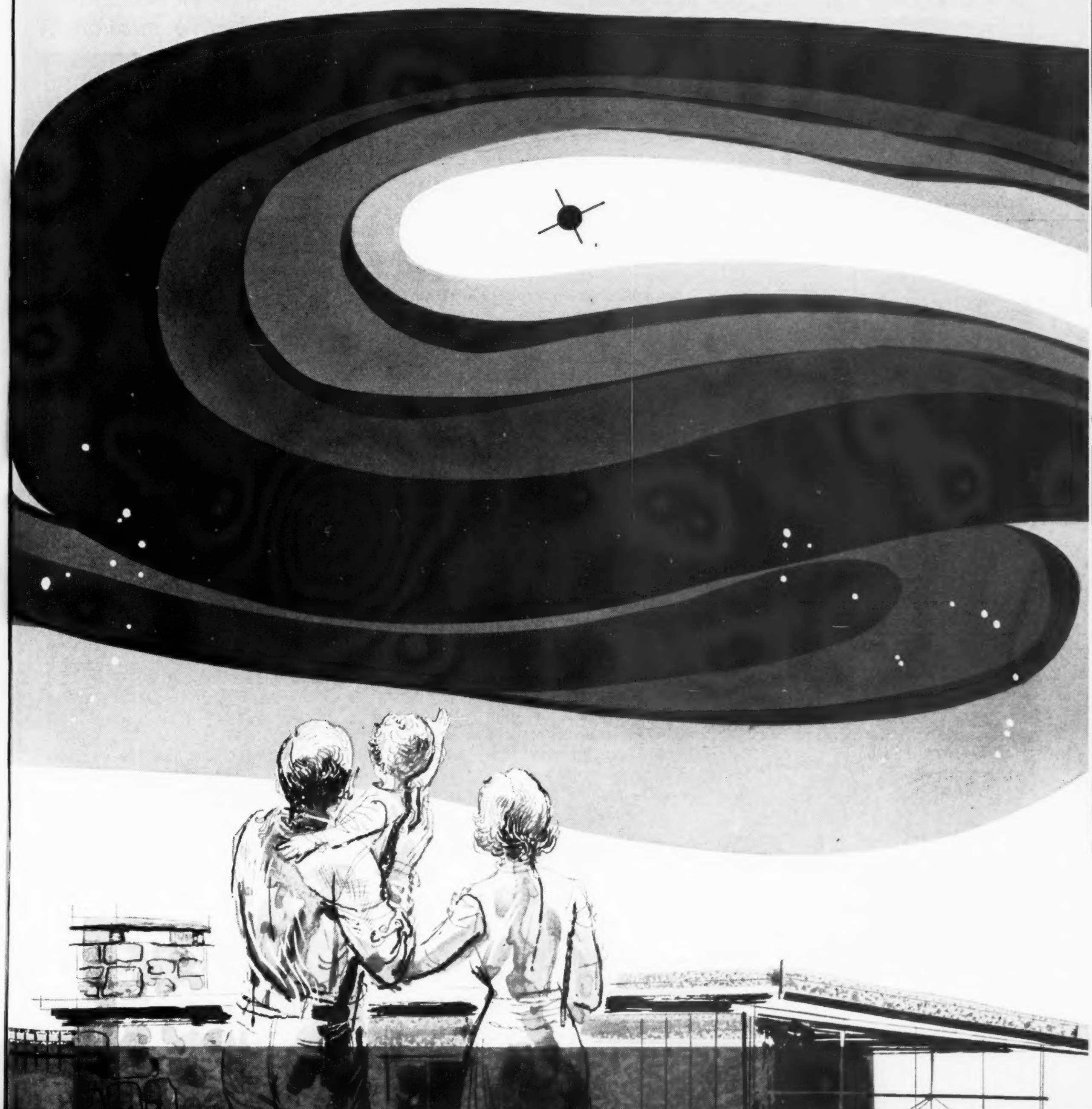
These general observations on Russian attitudes and accomplishments on the high road to space flight preface summary notes on the Soviet space program which will appear periodically in Astronautics.

—John Newbauer

Polaris Launching Tests



A dummy Polaris missile (left) exits from a prototype launcher during successful launching system tests jointly conducted by Westinghouse Electric, developer of the launcher, and Lockheed Missile Systems Div. At right, launcher belches smoke while dummy missile falls toward San Francisco Bay, from which it will be retrieved for study and re-use.



Meteorological Systems

(CONTINUED FROM PAGE 27)

network is desired, the AN/GMD-2 system would be the logical choice.

As stated earlier, wind data could be obtained by tracking a drifting parachute sonde while it descends. Two important problems must be considered in this regard. The first is whether or not parachutes with its payload will respond to changes in wind velocity and direction quickly enough to provide useful information. The second problem is that of opening a parachute at the desired maximum altitude.

The results of tests with the Wasp system indicate that the first problem may not be serious. Few data are available regarding the second problem, although it is believed that parachute opening at altitudes up to 175,000 ft should certainly be possible. Russian reports indicate that parachute opening at 210,000 ft may be possible.

Less critical problems are stability and descent rates. The use of guide-surface parachutes should provide adequate stability as well as improvements in wind tracking efficiency. A compromise must be made between the descent rate at the top of the trajectory, where it should be slow enough to measure low wind speeds, and at lower altitudes, where the rate should be rapid enough to prevent the sonde from drifting out of range.

An alternate plan might involve the use of balloons, rather than parachutes. A possible disadvantage with balloons would be the increased rocket payload due to the weight of inflation equipment. If only wind data are required and radar with adequate range can be employed for tracking, thus eliminating a payload requirement, very light balloons and inflation equipment can be used.

Temperature Measurements

Of the many types of temperature-sensing elements available, three are worthy of consideration: Thermocouples or theropiles, resistance wires, and thermistors. All three are light in weight, have minimum volume, and can be designed to withstand the acceleration and shock encountered in rocket flight.

A thermocouple has the following additional features—a metallic surface which can reflect solar radiation, and a small thermal mass which has a high speed of response and reliability. However, two features limit its usefulness for meteorological soundings—the need for a reference junction or its equivalent, and the additional circuitry required to telemeter an amplified *emf* signal.

A resistance wire can also have good reflecting characteristics and a fast response time. However, resistance wires have relatively low sensitivity to temperature changes, and the long length of wire needed to provide a useful change of total resistance with temperature would require a fairly elaborate mounting arrangement. For a short length of wire, the bridge circuit required to provide sufficient sensitivity would greatly increase the circuitry costs.

Thermistors have none of these undesirable features. They have a very high negative temperature coefficient of resistance, can be fabricated into any reasonable shape and size, can have response times of one second or less, can be provided with reflective surfaces, and are inexpensive. Present use in U. S. Weather Bureau and Army Signal Corps routine balloonsondes has established their reliability under a multitude of weather conditions.

Although it is felt that the design of the thermistors presently used for balloon soundings is not satisfactory from ruggedization or radiation viewpoints, a small bead thermistor with a reflective coating is regarded as the most feasible choice for a temperature-sensing element in the rocketsonde. In addition, the circuitry required to telemeter temperature information from thermistors is extremely simple. The thermistor is included in the grid circuit of the blocking oscillator and the thermal resistance changes of the sensing element are telemetered as a pulse modulation of the carrier frequency.

Two principle sources of error should be considered—solar radiation and aerodynamic heating during descent. If a thermistor bead coated with evaporated aluminum is used, a maximum error from solar radiation of 1.5 C can be expected. The maximum error to be expected from aerodynamic heating is approximately 2.5 C. Both errors can be expected to decrease as the sonde descends.

The most important component of the system from both the economic and the operational points of view is obviously the rocket vehicle. Several designs can be visualized, depending on how the rocket designer prefers to handle such parameters as type of propellant and grain, diameter, burning time, and acceleration.

For the Civil Defense Administration study, it was decided that the best way to obtain a realistic idea of probable cost was to determine certain minimum specifications and submit these to rocket manufacturers for estimates. Several rocket manufacturers very kindly agreed to cooperate and provided informal estimates and de-

signs.

The principle specifications were that the rocket:

1. Reliably attain an altitude of 160,000 ft. This altitude allows 10,000 ft for nose cone separation and deployment of parachute. Since positional accuracy is not of prime consideration, a moderate amount of dispersion of the rocket trajectory can be tolerated.

2. Carry a payload, including the nose cone, of 12 lb in a volume of 300 cu in. These weights and volumes were conservatively estimated, based upon a minimum amount of miniaturization and ruggedization of the instrumentation and a maximum amount of power, and therefore represent a maximum payload. In all likelihood, reductions can be made from these values. If so, rocket performance will be enhanced.

3. Have sufficiently low acceleration not to require excessive and expensive ruggedization of the instrumentation, yet sufficiently high to provide flight stability under normally anticipated weather conditions. The launching system will obviously influence this design specification. It was thought that accelerations of the order of 25 g's or less would be reasonable.

4. Have a mass produced unit price sufficiently low to render the entire system economically attractive. This specification is obvious and should be given overriding consideration. However, it does imply that extensive and more expensive ground facilities could be tolerated if the unit cost of the vehicle could thereby be reduced.

Estimates for the cost of rocket vehicles produced at the rate of 100,000 per year varied from $75 to $375 each. Estimates for the cost of instrumentation and parachutes ranged from $45 to $110 per unit. A careful consideration of cost estimates and designs indicated that the probable cost of expendable equipment could be expected to be on the order of $155 per round.

It is impossible to discuss all aspects of the problem of developing an inexpensive rocketsonde in this short review. Obviously, such problems as antenna design, tracking speed, launching system, descent rates, accuracy and sensitivity of measurements, etc., are also important. Although these problems are not covered here, investigation showed that they are all amenable to solution with a reasonable development program.

In view of the additional information that can be obtained and the increased reliability that can be achieved, the estimated production cost of expendable rocketsonde units seems quite favorable. The potential mutual benefits to both meteorology and rocketry certainly seem to make the development effort worthwhile.

ARS news

Seen at the ARS-IAS Space Conference in San Diego

This distinguished panel opened the successful two-day Space Exploration conference at San Diego co-sponsored by the local ARS and IAS Sections and ARDC. Left to right: A. C. Hall, Donald Michael, Morton Alperin, Homer J. Stewart and Theodore von Kármán.

John E. Naugle of Convair, co-chairman of one of the technical sessions, introduces a speaker.

Part of the audience of more than 600 who attended the conference listen attentively during the panel discussion.

E. R. Van Driest, chief scientist of North American's Missile Development Div. and chairman of the first technical session, makes a point.

MORE THAN 600 scientists and engineers all having an interest in astronautics turned out for the Space Exploration conference in San Diego Aug. 5–6 sponsored jointly by local ARS and IAS sections and ARDC. The highly successful meeting, originally expected to be a purely local affair, grew to a point where it drew registrants from all over the country.

The meeting opened with a panel discussion of the economic, sociological and technological aspects of astronautics, and continued with three technical sessions, one classified. Some 18 papers were presented, ranging from discussions of the radiation intensity in space to a progress report on the X-15.

The stimulating discussion which opened the meeting keynoted the two-day conference. C. L. Critchfield, director of scientific research for Convair, introduced the panel members—Theodore von Kármán; Homer J. Stewart, Cal Tech; Morton Alperin, Directorate of Advanced Studies, AFOSR; Donald Michael, Dunlap and Associates; and A. C. Hall, Martin-Denver—and moderated the discussion.

The discussion centered primarily on the possible impact of space flight on man and his environment, answering the old question of "Why space flight?" in a number of different ways.

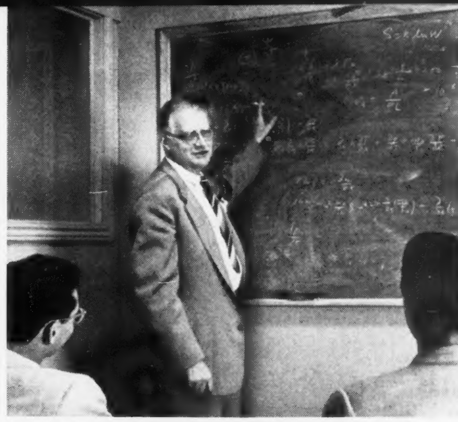
It was apparent from the discussion that Dr. Von Kármán was enthusiastically in favor of intelligent space exploration. He pointed out that in the past scientists have had difficulty explaining the "why" of their basic research, and it is no different for space scientists. However, he added, we can already see how astronautics will result in great advances in knowledge in such fields as astronomy, meteorology, physics of matter, field theory and atmospheric entry problems. He also warned against space ventures carried out for purposes of prestige or publicity alone.

Dr. Stewart made the point that we are just beginning to scratch the surface and are hardly in a position today to know all the advantages which will eventually accrue to man. He pointed out that present delivery costs—about $30,000 for each pound placed in orbit—preclude an elaborate effort at this time, but that foreseeable improvements in structures and propellants could bring that cost down to something like $300 a pound, and that when this happens the rate of return from space exploration will increase sharply.

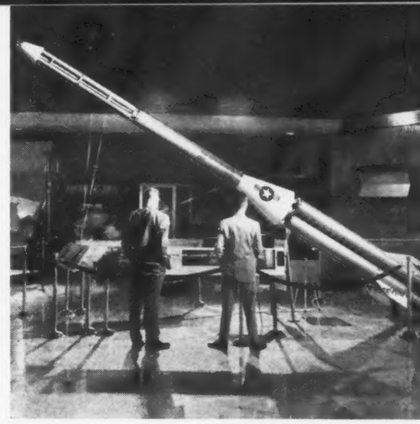
Dr. Alperin asked whether it was really necessary to find a justification for astronautics, noting that, just as research in any pure science yields knowledge useful to the military, so, undoubtedly, will space flight. He urged that we go ahead with our research, get it funded and worry about applications later. He stressed that this has been the pattern in research before, and will apply to space exploration as well.

It was pointed out by Dr. Michael that space pioneers are risking the loss

Progress Report on Aeronutronic Systems, Inc.



Dr. Montgomery H. Johnson, Director of Aeronutronic System's Advanced Research Staff, discusses problems related to lunar research flights. Other Advanced Research Staff interests include the study of air opacity, infrared missile emissions, and high altitude and free space nuclear explosions.



Far Side Missile developed by Aeronutronic for USAF Office of Scientific Research. Four-stage rockets like this were balloon launched and fired to record breaking altitudes where they measured the Earth's magnetic field and cosmic radiation intensities.

[H]ow Aeronutronic is meeting the needs of advancing science and technology

The Ford Motor Company established Aeronutronic Systems, Inc. to engage in the development and manufacture of highly technical products for [m]ilitary and commercial purposes. In a time of expanding science, Aeronutronic is meeting the technological needs of the Nation. A few of Aeronutronic's broad interests and activities are illustrated here.

ASI Model IL-101 Subminiature Transmitter provides exceptional frequency stability under high acceleration space conditions. Size of unit: 1.1 x 1.4 x 2 inches. Weight: less than 5 ounces. Output: 150 ± 10 mw.

erial view of Newport Beach, California, where Aeronutronic Systems, Inc. is building modern, new facilities carry out military and commercial programs involving the most advanced research, development, experimen-tion and production. Aeronutronic's new facilities are located 40 miles south of Los Angeles on a mesa over-oking Newport-Balboa Harbor and the Pacific Ocean.

Prototype model of ASI Digital System Simulator. Unit is designed to give direct check of reduction of logical equations, to study a system's operations prior to construction, and to study alternate logical designs.

AERONUTRONIC SYSTEMS, INC.

a subsidiary of Ford Motor Company

For information about outstanding career opportunities, and for booklets on ASI's interests, facilities or products, address: Aeronutronic Systems, Inc., Building 20, 1234 Air Way, Glendale, California.

On the calendar

1958

Oct. 13–15	National Electronics Conference, sponsored by IRE, AIEE, EIA, Hotel Sherman, Chicago.
Oct. 14–16	**ARS New Mexico-West Texas Section and American Meteorological Society High Atmosphere Conference, El Paso, Tex.**
Oct. 23–25	International Symposium on Rockets and Astronautics, sponsored by Deutsche Gesellschaft fur Raketentechnik und Raumfahrt, Essen, West Germany.
Oct. 23–25	National Society of Professional Engineers Fall Meeting, St. Francis Hotel, San Francisco.
Oct. 30–31	15th Annual Display of the Aircraft Electrical Society, Pan Pacific Auditorium, Los Angeles.
Nov. 6–7	National Specialist Meeting on Dynamics and Aeroelasticity, sponsored by IAS Texas Section, Texas Hotel, Ft. Worth, Tex.
Nov. 6–7	5th Annual Meeting of the Professional Group on Nuclear Science, Villa Hotel, San Mateo, Calif.
Nov. 10–12	AF School of Aviation Medicine-Southwest Research Institute Space Symposium, Hilton Hotel, San Antonio, Tex.
Nov. 17–21	**ARS 13th Annual Meeting, Hotel Statler, New York, N.Y.**
Dec. 17	Wright Brothers Lecture, sponsored by IAS, Natural History Bldg., Smithsonian Institution, Washington, D.C.
Dec. 26–31	125th Annual Meeting of the American Assn. for the Advancement of Science, Washington, D.C.

1959

Jan. 26–29	27th Annual IAS Meeting, Sheraton-Astor Hotel, N.Y.C.
Feb. 3–5	14th Annual Technical and Management Conference of the Reinforced Plastics Div. of The Society of the Plastics Industry, Edgewater Beach Hotel, Chicago.
March 19–20	Flight Propulsion Meeting, sponsored by IAS, Hotel Carter, Cleveland, Ohio.
March 23–25	**ARS Spring Meeting, Daytona Beach, Fla.**
April 5–10	Fifth Nuclear Congress of Engineers Joint Council, Cleveland Auditorium, Ohio.
April 6–10	40th Annual Convention of the American Welding Society, Chicago.
May 25–27	**National Telemetering Conference, co-sponsored by ARS, AIEE, IAS, and ISA, Denver, Colo.**
June 8–11	**ARS Semi-Annual Meeting, San Diego, Calif.**
June 11–13	1959 Heat Transfer and Fluid Mechanics Institute, Univ. of Calif., Los Angeles.
Aug. 24–26	**ARS Gas Dynamics Symposium, Northwestern Univ., Evanston, Ill.**
Nov. 16–20	**ARS 14th Annual Meeting, Washington, D.C.**

of hard-won public interest and political support by presenting a confused picture of the purposes and intent of space exploration to the public. He also noted that space exploration may not solve the impending overpopulation problem facing us on earth even if an inhabitable planet is found, since modern technological civilizations of the type capable of producing space ships do not produce hardy souls with the pioneering spirit necessary to colonize another planet, newspaper stories about Mars trip volunteers notwithstanding.

Increasing research and development costs involved in developing space vehicles pose a critical problem to the aircraft industry, Dr. Hall pointed out. Old-line aircraft industries must not only build R&D organizations and fend off competition from newcomers, but also plow a share of earnings back into research, he warned.

A few highlights from the technical papers presented at the conference:

Robert E. Roberson, Autonetics Div. of North American, reviewed several satellite attitude control systems, including spin stabilization, flywheel stabilization, and natural and artificial inherent vehicle stabilization, noting that the physical basis for all these systems is now well established, but much needs to be done in the field of specific satellite applications.

Milton U. Clauser, of the Ramo-Wooldridge Physical Research Lab, in his paper on space propulsion systems, concentrated on ion systems and rockets whose gases are heated by fission reactors and thermonuclear reactions, stressing the need for development of such systems for space exploration.

George A. Hoffman of Rand Corp., reviewing materials for space flight, plumped for "whiskers" (August, 1958, Astronautics, page 31), noting that if a means of fabricating metal whiskers and incorporating them into structures is found, it could reduce airframe structural weights by as much as 80 per cent.

In a paper on "Power Supply Problems in Ion Propulsion," A. L. Huebner and R. H. Boden of Rocketdyne discussed the implications of using various liquid metals as heat exchange fluids in ion rockets, as well as the problem of keeping down the size of the cooling radiator and its relation to reactor power output.

An interesting paper on space communication problems was presented by M. G. Chatelain, Antenna Research Lab, who suggested use of a metallic spiral printed on the surface of a plastic balloon as either a dipole or slot antenna to save weight and maximize frequency band width.

H. A. Lieske of Rand Corp. discussed the precision navigation problem involved in choosing trajectories for circumlunar flights originating from and returning to earth. A trip of this type would take six to 10 days using the trajectories discussed by Dr. Lieske.

One unclassified paper at the classified session, by John DeNike of Martin Co., assumed that a base was to be set up on the moon and analyzed the logistical problems involved in supplying and maintaining such a base. He noted that the amount of supplies necessary to support a manned base of this type would not be unreasonable.

J. D. Hardy of the Johnsville, Pa., Naval Air Development and Materials Center described the results of test runs by pilots "flying" in a simulated cockpit mounted on the center's 50-ft centrifuge, which simulates the acceleration loads a pilot might experience in such vehicles as the X-15.

J. E. Cook of Holloman AFB, in a paper on "Radiation Effects on Living Tissue," described balloon experiments in which mice were lifted to altitudes of 80,000 ft to study the impact of low-energy heavy nuclei on living flesh and blood. He noted that to date there are no indications of any hazards existing at such altitudes.

The last paper of the meeting, presented by John E. Naugle of Convair, reviewed the significance of the recent satellite data (July, 1958, Astronautics, page 40) indicating an intense belt of radiation at altitudes of 600 miles and higher. Dr. Naugle stressed the point that a good deal more must be learned about this radiation before we can expose man to it for any length of time.

Addison M. Rothcock, NACA assistant director of research, was the featured speaker at the banquet on Tuesday evening, Aug. 5, attended by some 270 guests. Dr. Rothcock discussed the NASA Act, and the organi-

zation of the new agency and its role in the nation's civilian space flight effort.

In the course of his address, he noted that because of the psychological effects on the people of the world, who first circumnavigates the moon and orbits a man in space and safely returns him to earth, has become very important.

"It is time for these things to be done," he added. "The nation or group of nations which does these things first and continues to do them will improve its chances of having its political philosophy accepted throughout the world."

Richard D. Linnell of Convair was general chairman of the meeting, and he and his colleagues are to be congratulated for the part they played in making the conference an outstanding success.

—William H. Dorrance

Separate Meetings For ARS and ASME

Because of the rapid growth of ARS, and the increasingly large attendance at meetings, ARS and ASME will in the future hold national meetings separately, although continuing to enjoy reciprocal privileges, such as unrestricted attendance at technical sessions, and continuing to cooperate closely, as they have for 13 years. This year, ARS will hold its Annual Meeting Nov. 17–21 at the Statler-Hilton in New York; ASME will meet Nov. 30 through Dec. 5 at the Hotels Statler-Hilton and Sheraton McAlpin.

SECTIONS

Cleveland-Akron: Newly elected officers of the section for 1958–59 are Paul M. Ordin, president; Howard W. Douglass, vice-president for Cleveland; Adolph L. Antonio, vice-president for Akron; and Paul E. Grevstad, secretary-treasurer. Besides its regular monthly meetings, which in coming months will feature talks on NASA and Minuteman, the Section plans a joint ASME-ARS dinner meeting in Cleveland for Jan. 1959 and another joint meeting with IAS in Akron in Feb.

—Harold W. Schmidt

Florida: Some 50 members and guests met July 24 at the Missile Room of Patrick's Officers Club to hear R. B. Morrison of Ramo-Woodridge describe the Thor-Able project. Dr. Morrison explained that Thor-Able is a research re-entry vehicle composed of off-the-shelf components modified as little as possible to make it immediately useful. He illustrated his discussion with a number of fine slides.

The local ARS and IRE groups gave a party July 26 for departing Florida section vice-president L. M. Orman. Bill Duvall of Douglas will take over for Col. Orman.

—Ballard Small

Southern California: In the July 24 meeting held at the Institute of Aeronautical Sciences, Los Angeles, A. V. Cleaver, assistant chief engineer of Aero Engine Div., Rolls-Royce Ltd., Derby, Eng., spoke on "A Current British View of Rocketry." He said there are two popular misconceptions in the U.S.—that nothing is ever done outside the U.S.A. and that every other country is competing in all fields with us.

Looking to the Future at Cleveland-Akron

New officers and key members of Cleveland-Akron—(l to r) Paul Grevstad, Pierce Angell, Edward Rapp, Paul Ordin, Howard Douglass and Adolph Antonio —meet to plan section activities for the fall and coming year. Pierce Angell is a director, and Ed Rapp heads the membership committee.

Both these views are quite wrong. Britain, for example, made big contributions in nuclear energy, gas turbines, and radar, but cannot economically compete with the U.S. in all fields of technology. The annual defense budget of Britain is only about $4 billion compared with about $45 billion for the U.S.A.

In common with other European countries, Britain has specialized in one or two fields. Rocketry has not been one of them. British achievements in rocketry have not been particularly outstanding, compared, say, with her achievements in the field of jet engines. Yet she has made several novel contributions.

During WW II, Britain did extensive work on small solid-propellant rockets, mainly unguided projectiles. Intelligence reports on V-2 and on rocket development for aircraft and missile propulsion stimulated interest. The Royal Aircraft Establishment (RAE) at Farnborough commenced a limited program with a rocket engine using lox and gasoline. Originally the rocket engine was intended for assisted takeoff of aircraft, but for one ton of thrust the unit itself weighed almost one ton. Work also went ahead on a missile, the LOPGAP (lox-petrol ground-to-air projectile) which only evolved as a test vehicle.

The Guided Projectile Establishment, an RAE department, later moved to Westcott. British aircraft firms began entering the field of guided weapons. Woomera was established as the main missile testing ground.

Britain concentrated on ground-to-air and air-to-air weapons, using radar and infra-red guidance systems. A typical ground-to-air missile was the Bristol *Bloodhound* using rocket boost and a ramjet sustainer. The British Navy's *Seaslug* started out as a liquid-propellant rocket vehicle, but now uses a solid propellant. So did the English Electric *Thunderbird*. In fact, the trend has been to leave liquids and to use solids almost exclusively for these classes of missiles.

Britain's most original work in rocketry has been done with aircraft propulsion. At the end of WW II, much German information became available. Moreover, as the German Walter concern was in the British Zone of occupation, many Walter scientists came to work in Britain. Also Britain had concentrated hydrogen peroxide (high test peroxide, HTP) available in bulk. Even before the war the British Government had been offered 80 per cent peroxide by a British firm. The tendency was therefore for British rocket work to start off with the HTP. Examples are found in the Napier missile motors and in various aircraft engines.

Britain is interested primarily in rapid-climb interceptors, which need mixed power plants—jets and rockets. Three projects of this type were started. Armstrong Siddeley produced the 2000 lb thrust Snarler, which used lox. This engine was flown experimentally in 1950. Then that company built the Screamer, which used lox and kerosine with water cooling. This engine was in the 8000 lb thrust range and formed the main engine of a fighter with a jet engine as the auxiliary power plant for use when the rocket engine had consumed its propellants. About 1956, the Ministry of Supply decided that liquid oxygen was not a suitable oxidizer for manned interceptor aircraft and stopped the project. Now Armstrong Siddeley is working on other power plants using HTP.

Napier produced the Scorpion, HTP kerosine, two-barrel engine, and the De Havilland Engine Co. produced the Sprite and the Super Sprite. Comet I was to have used the Sprite for assisted takeoff from high-altitude airfields. The Super Sprite is used as a booster for the Valiant, V-bomber. This company also produces the Spectre to the same specifications as the Screamer. It is a thermal-ignition type of engine in which the HTP is decomposed by a catalyst in a chamber ahead of the fuel injection. Spectre also has the unusual feature of a topping turbine, with the turbine exhausting into the main chamber. The hot gases give automatic ignition without critical starting conditions.

This engine has, in fact, been controlled over a thrust range of 15:1 without combustion instability; and there have been extensive tests in England with the Spectre running for over 70 min, during which it consumed 45 tons of HTP. Present HTP consumption in the British rocket industry amounts to about 1500 tons per year for R&D alone. It is also interesting to note that no significant accidents in flight or in test beds have occurred that could be directly attributed to the use of HTP.

Now there is active work on the British IRBM, with Rolls-Royce making the propulsion unit under license from Rocketdyne. But as to a space program, there is none officially sponsored in Britain, nor is there likely to be one. Only private studies are being made, for example, on ion propulsion.

The only significant British rocket society has been the British Interplanetary Society, formed in 1934. It has always been concerned mainly with space flight problems but has also been interested in rockets. From small beginnings it now has more than 3000 members and it was largely instrumental, in 1950, in forming the IAF.

British reaction to the launching of a Soviet earth satellite was not quite so much of surprise as in the U.S. Already it had been concluded in Britain that the U.S.S.R. was trying hard and with large resources. Britain also was not so personally involved as the U.S. and accordingly did not feel any blow to national pride.

Mr. Cleaver answered many questions from his audience during a long discussion following his talk.

—Eric Burgess

Wichita: The July dinner meeting featured a talk by Phillip W. Russell, member of the Wichita Moonwatch team, on "Orbital Data and Preliminary Analyses of Satellites." Dr. Russell explained how data like that taken locally contributes to the charting of satellite paths and how, out of a mass of detailed tracking data, expressions have been developed for predicting and following back the orbit of a satellite.

The Wichita section is making plans to present for its members and others in the area—people at Beech, Boeing, Cessna and the University of Wichita —the 17-lecture space-technology film series produced by Ramo-Woodridge in cooperation with the University of California at Los Angeles. This film series, which has received much favorable comment, will give some real substance to our local educational program in rocketry and space technology.

—R. Harvey Anselm

CORPORATE MEMBERS

Douglas is building a $10 million facility with a 1-ft "trisonic," a 4 ft square supersonic and a 24 in. diam. hypersonic (higher than Mach 10) tunnel with its own funds on a 10-acre site in El Segundo, Calif. The small trisonic tunnel, begun in 1956, served as a pilot model for the other two. The supersonic tunnel will be completed in early 1959, and construction of the hypersonic tunnel will begin late this year.

Boeing will give some 600 AF and CS specialists maintenance and operations training on the B-52G missile-platform bomber at its Witchita, Kan., plant. These specialists will in turn form a training cadre for field units when deliveries of the B-52G begin. The first B-52G rolled out of Boeing in July.

Avco's R&D Div. has taken up headquarters in a new $16 million center at Wilmington, Mass., with only the Electronic Systems Dept. re-

maining in its present Boston site. Facilities include four main integrated buildings providing over 400,000 sq ft of floor space and covering some five acres on 100-acre grounds. In addition, the center will include Avco's ballistic range and arc wind tunnel, buildings for which are still under construction. Avco Research Lab, a separate division of the corporation, will also move to this center later in the fall.

Martin Establishes Space Flight Division

Martin has formed a Space Flight Division, with headquarters in Baltimore, to direct the Dyna-Soar team—Martin, project direction and propulsion; Bell Aircraft, airframe; Minneapolis-Honeywell, guidance system; Bendix Aviation, communications, telemetry, hydraulics, and electrical power system; Goodyear Aircraft, crew-escape capsule and radar system; and American Machine and Foundry, ground equipment. Staffed by members of both Martin and Bell, the new division will have as general manager George S. Trimble Jr., a Martin vice-president, and as assistant general manager, R. J. Sandstrom, a Bell vice-president.

Answers to September Space Technology Quiz

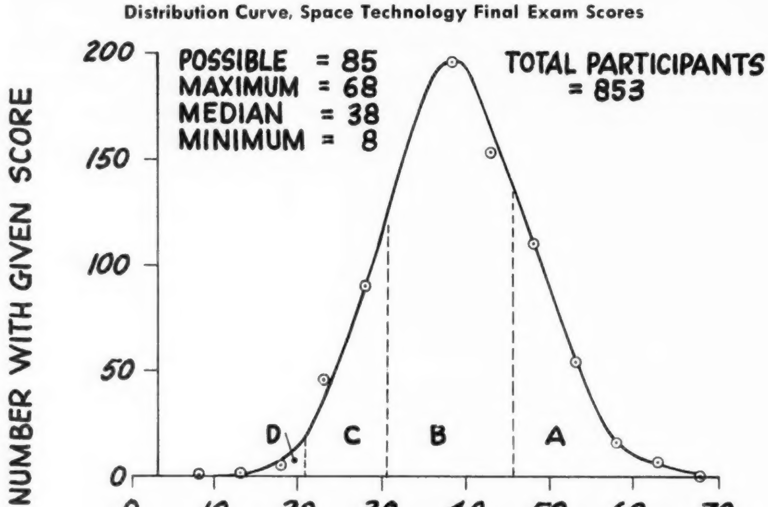
Correct answers to the Space Technology Quiz which appeared in last month's ASTRONAUTICS (page 22) are as follows:

1. (4); 2. (5); 3. (2); 4. (1); 5. (2); 6. (4); 7. (1); 8. (4); 9. (3); 10. (2); 11. (2); 12. (4); 13. (2); 14. (2); 15. (2); 16. (4); 17. (5); 18. (4); 19. (3); 20. (2); 21. (2); 22. (4); 23. (5); 24. (3); 25. (2); 26. (4); 27. (2); 28. (3); 29. (4); 30. (3); 31. (4); 32. (4); 33. (4); 34. (2).

35. (1); 36. (4); 37. (2); 38. (4); 39. (1); 40. (3); 41. (4); 42. (4); 43. (2); 44. (5); 45. (4); 46. (2); 47. (5); 48. (3); 49. (1); 50. (3); 51. (2); 52. (1); 53. (5); 54. (4); 55. (1); 56. (2); 57. (2); 58. (5); 59. (1); 60. (3); 61. (3); 62. (2); 63. (3); 64. (4); 65. (3); 66. (4); 67. (1).

68. (2); 69. (4); 70. (3); 71. (5); 72. (4); 73. (5); 74. (3); 75. (4); 76. (5); 77. (2); 78. (4); 79. (2); 80. (3); 81. (5); 82. (3); 83. (1); 84. (5); 85. (3); 86. (2); 87. (1); 88. (2); 89 (4); 90. (4); 91. (2); 92. (5); 93. (1); 94. (1); 95. (2); 96. (5); 97. (4); 98. (4); 99. (1); 100. (1); 101. (3); 102. (3).

Distribution Curve, Space Technology Final Exam Scores



Distribution curve shows how students taking Space Technology Course given by Univ. of California did on final exam. Exam had only 85 questions; quiz printed last month was enlarged to 102 questions.

Instrumentation—Part II

(CONTINUED FROM PAGE 37)

132 measurements.

The SCO's are of the standard telemetering variety. The SMU's add or subtract for zero adjustment, attenuate or amplify for adjusting range or span, and substitute calibrating for signal voltages. This latter function can be accomplished manually, step by step, or automatically through all the SCO's on a tape track.

The transducers are to some extent the same as those used in flight telemetering. Wherever possible, they are of the potentiometer type, which give high signal-level output. High-level signals are used when possible.

AC-type transducers and signal functions are shown below the dotted line in the drawing, p. 36. The AC signals come from reluctance or inductance transducers, self-generating flow meters and some autopilot signals, such as gyro positions. In some instances, AC signals may be discriminated and sent through the remainder of the system as amplitude signals.

Monitoring and quick-look indicators and recorders are shown in the upper part of the drawing. About 30 such measurements are made when the FM system is fully operative.

Instrumentation at a captive-test base is distributed as follows: Transducers are located on the missile and ground support equipment. Patch panels and signal modifying units are in a transfer room near the test stand. The remainder of the system is in the blockhouse. Also in the blockhouse are sequence recorders and a partial data-processing station for checking out the FM instrumentation system.

The kind of measurements to be made and the stability of critical components, such as transducers, affect the operating time and accuracy of the system in several ways. The time-consuming operations in preparing instrumentation for a test are setup, checkout and calibration, and trouble shooting. Some 80 per cent of the measurements can be made routinely. Generally, only high-frequency and high-accuracy measurements must be specially handled.

Looking at routine measurements, we see, first, that adequate patching facilities are the prime consideration in reducing setup time, and, second, that checkout and calibration procedures must be simple. The first is a straightforward design problem once operating procedure is established. As to calibration and checkout, if it is remembered that the problems of laboratory work need not be taken into the field, operations can be made straightforward without loss of valuable time. There must, of course, be confidence in the stability of precalibrated instruments, e.g., voltmeters and transducers, and good engineering insight as to the kind of error that might arise from the way the instruments are used.

Ground Land Lines

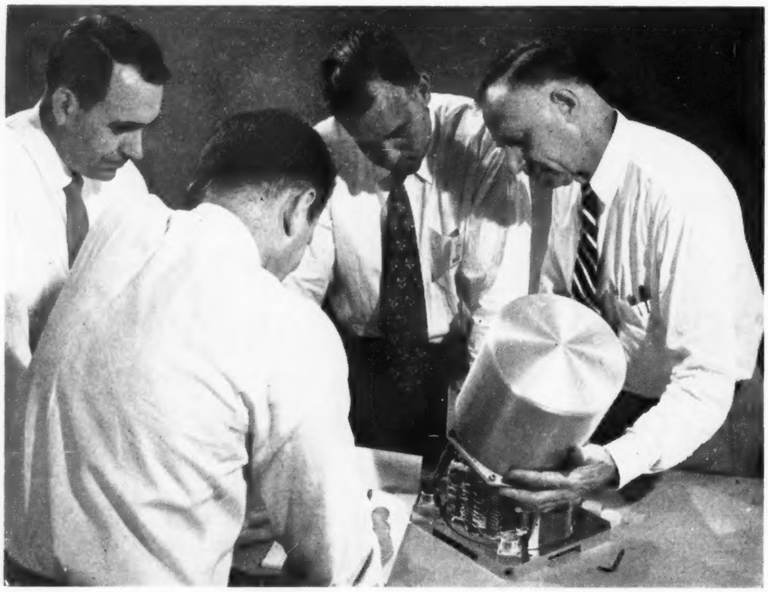
Problems of leakage, crosstalk and noise in long land lines have come in for some discussion lately. We need only repeat here that effort spent in a good grounding system is well repaid and that the length of lines between the transducer and the point of entry into the system should be as short as practical for checkout purposes.

Some workers in this field have standardized transducers to the point where they are interchangeable, thus making it unnecessary to refer to serial number and associated calibration data. The transducer output is as dependable as the reading of a voltmeter. We have reached this state of the art in many areas, and are rapidly approaching it in the area of nonroutine measurements.

As mentioned, signal-modifying units have associated with them a manual and/or automatic switching arrangement for injecting calibrating voltages into the recording system. With confidence in the transducer to convert a physical function into a voltage without drift, it is a relatively easy matter to calibrate the rest of the system by automatically injecting calibration voltages. This eliminates the laborious, time-consuming process of applying accurately known calibrating stimuli to transducers.

The automatic, or voltage injection, method of calibrating those elements that show drift is so simple that it requires only a few minutes before and after each test. Voltages are injected into the telemetering system during flight and are used by the ground station to apply automatic corrections. System tests which precede a major test also give the instrumentation a good functional check.

The most time-consuming thing in end-to-end calibration—communication between the man applying stimulus to the transducer on the missile, the man making adjustments in the transfer room, and the man reading-out in the blockhouse—can, then, be avoided in routine measurements by either recalibrating or replacing a transducer whose calibration is in



It Came From Outer Space

Put there and brought safely back by the historic May 18th Jupiter, this "warhead device," designed and built by Ford Instrument Co., in cooperation with ABMA, functioned perfectly during the flight, as determined by telemetering. It was not previously revealed that the Jupiter nose cone contained functioning instruments. Examining the little mystery are, left to right, William Schneider of Picatinny Arsenal (back to camera), Michael Moscarello of Ford, Robert Schwartz of Picatinny and John Kallenberg of Ford.

question and by automatic voltage calibration of the remainder of the system. This procedure also facilitates trouble shooting and avoids time delays that permit drifts to become large enough to affect accuracy.

Good overall accuracy has been obtained through use of this system. The processing station gives digital data accurate to ± 1 per cent or better and analog data to ± 1.5–2 per cent. The FM system is good to ± 4 per cent for routine measurements; actual testing thus far has shown an accuracy of ± 1 per cent on 85 per cent of measurements taken. Where required, the accuracy of the FM system can be improved by using special transducers, suppressing zeros, etc.

The trend in missile instrumentation, in addition to the kind of automation described here, is statistical treatment of measurement accuracy. Instead of using calibration curves for each measurement, a tolerance about a linear transfer function is used. That is, the best (least square) straight line is drawn through the calibration data, and the zero offset and slope of this line, together with the tolerance, is specified for each measurement. The actual data used in this process consists of the straight line of the transducer and the transfer function obtained from automatic calibration of the remainder of the system.

At Convair, we had initially planned to have automatic linearity-compensation equipment in the data-processing station, but found that transducer and other component nonlinearities did not warrant it. This condition will improve as equipment development progresses. Even now, many transducers are interchangeable.

Beyond these points, there seems to be a general tendency to divide data into two classes: (1) Transient data, or data with a high *time* accuracy requirement, and (2) semi-steady-state data with a high *amplitude* accuracy and a relatively low time accuracy. The former will probably always be treated by some form of analog plotting, but there is a tendency to treat the latter by digital methods. We may some day even have more digital transducers. The "Vibratron" and frequency-generating flowmeter are approaching this.

White Succeeds Kincheloe

AF Capt. Robert M. White of New York City has been named to succeed Capt. Iven C. Kincheloe Jr. in the AF X-15 test program next year. Capt. R. A. Rushworth will be used in similar AF programs. Capt. Kincheloe was killed in a jet plane crash at Edwards AFB, as noted.

Missile market

BY ROBERT H. KENMORE, Financial Editor

THE ONLY stock that failed to participate in the July advance led the August market with a dramatic 30 per cent increase. Bell Aircraft's price appreciation was concentrated in the two days following the company's announcement that it had successfully tested a rocket engine using liquid fluorine in place of liquid oxygen. This market action indicates two important facts:

1–The financial press, stockbrokers and investors have reached a much more sophisticated level of interpretation of the technical developments in the missile industry, and

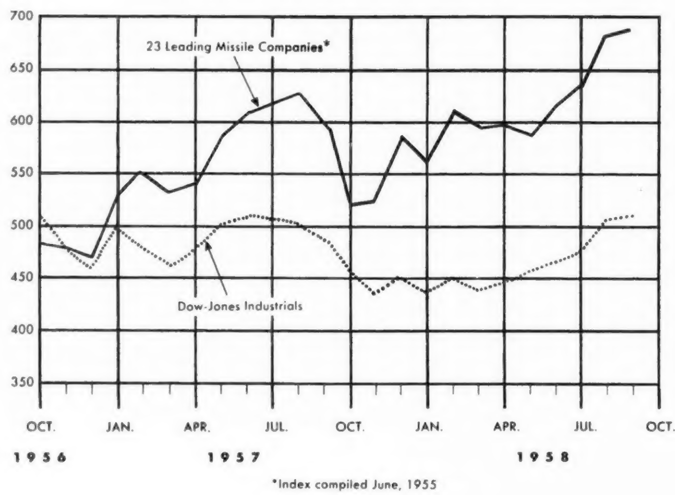
2–Corporate innovations, which come particularly frequently to missile industry companies, will affect security prices much more than general market or economic trends.

Offsetting Bell's 30 per cent advance, General Precision Equipment lost 15 per cent of its market value on drastically reduced earnings and an omitted dividend. Other wide moves were seen on the upside in Thiokol and Litton and by Marquardt on the downside. For both the missile index and the Dow-Jones, all individual movements cancelled each other out as the averages remained stable.

In spite of all the publicity being given to the "outrageously" high expenditures which we are being asked to make for missile and aircraft development, and overall defense in the cold war race with Russia, some figures relating these costs to our total Gross National Product will show that our economy could still support a significantly higher level of spending in this area.

The percentages top p. 61 show that total defense expenditures are still substantially below the average for the last seven years and that aircraft and missile expenditures have yet to show an appreciable rise (although the shift in emphasis from aircraft to missile has, of course, been marked). It is important to learn to ignore dollar figures and stick to more meaningful percentages when trying to determine what is "high" or "expensive," since dollars are constantly being blown up by inflation and do not take into account the overall growth in our economy. In the light of these considerations, the $39.6 billion defense ap-

THE MARKET AT A GLANCE



*Index compiled June, 1955

	Sept. 1958	Aug. 1958	% Change	Sept. 1957	% Change
Dow-Jones Industrials	508	505	+0.6	484	+ 5.0
Missile Index	683	678	+0.6	583	+17.0

RELATIONSHIP OF DEFENSE EXPENDITURES TO GNP
(Billions)

Year Ended June 30	GNP	Total Defense Expenditures	% of GNP	Aircraft and Missile Expenditures	% of GNP
1952	336	38.97	11.6	5.06	1.5
1953	360	43.71	12.1	7.72	2.1
1954	362	40.34	11.1	8.84	2.4
1955	379	35.53	9.4	8.76	2.3
1956	409	35.79	8.8	8.32	2.0
1957	432	38.44	8.9	10.08	2.3
1958	435	39.11	9.0	10.74	2.5

propriation set by Congress for fiscal 1959, generally considered some kind of record, would only represent 8.4 per cent of the Gross National Product estimated for mid-1959—the *smallest* figure since 1951!

From the table on corporate earnings it is evident that the first six months of this year have held mixed blessings for the missile makers. Just as evident, however, is the fact that investors have largely chosen to ignore earnings news when it was bad. Only two stocks declined between January 1 and August 29, although 12 of the companies reported lower per share earnings for the period, or failed to register any increase.

One of our readers has suggested that we make a survey of how many people reading this column actually do invest (or plan to) in missile securities. In order to get a meaningful figure, it would be extremely helpful if *all* readers of the "Missile Market" could drop me a postcard, simply indicating whether or not they own any securities of companies in the missile-rocket field. Please mail these to me at P.O. Box 175, New York 16, N.Y.

CORPORATE REPORTS[1]

Company	Sales (Million $)	Earnings per Share	Change in Earnings from 1957	Change in Market Price from Year-End
Chance Vought	$154	$4.35	+123%	+47%
Raytheon	179	1.29	+59	+66
Litton[2]	83	2.12	+40	+32
Lockheed	466	3.30	+29	+35
Aerojet[6]	92	0.54	+29	+ 8
Northrop[3]	192	2.99	+28	+14
Ryan[4]	35	1.90	+24	+44
Boeing	861	2.78	+19	+17
Marquardt[5]	23	0.80	+11	+35
Bell	101	0.81	+ 3	+47
G. M. Giannini	5	0.58	—	+ 9
Thiokol	32	0.68	—	+26
General Dynamics	790	2.04	− 9	—
Hercules Powder	117	0.89	−14	+14
Martin	188	1.23	−19	+ 2
Douglas[6]	594	3.41	−24	−19
North American[7]	679	2.27	−32	+10
Bendix[8]	155	0.92	−34	+31
American Bosch	58	0.85	−46	+30
Thompson Products	142	1.29	−56	+12
Sperry Rand[8]	210	0.13	−63	+ 3
General Precision Eq	86	0.16	−93	−17

[1] For six-month period ending June 30, unless otherwise noted.
[2] Twelve months to July 31.
[3] Nine months to April 30.
[4] Six months to April 30.
[5] Twenty-eight weeks to July 19.
[6] Six months to May 31.
[7] Nine months to June 30.
[8] Three months to June 30.

Power Sources

(CONTINUED FROM PAGE 25)

struction might be to use a flat Fresnel lens. One might also consider using mirrors to heat a working fluid (or solid-stage conversion device) for subsequent generation of electricity. The conversion would be essentially the same as for any heat source.

As will be pointed out in discussing reactors, the weight of the conversion equipment and waste-heat radiator grossly predominates over that of the heat source, even including any required shielding. As a result, the use of solar energy in this fashion to generate large amounts of electricity does not seem attractive compared with nuclear energy. For small requirements, direct conversion through silicon cells seems more attractive, at least for the time being.

Quantum Operation a Limit

Photochemical reactions, silicon solar "batteries," and the like operate on a quantum principle. That is, they cannot usefully absorb quanta with wavelengths longer than a prescribed threshold value. Taking into account reflection, which lies between 30 and 50 per cent for silicon, and other losses, the efficiency of a p-n silicon solar converter, of the form illustrated on page 25, should be about 12 per cent above the atmosphere.

Current production cells, if carefully selected, run near this figure, thus delivering about 135 watts per sq meter of exposed area. A bare single cell, on a weight basis, will deliver about 30 watts/lb in full sunlight. Current photochemical research indicates a performance of about 1 watt per gram of solution. Actual cell groups may deliver less than 3 watts/lb. Two of the prime difficulties with current cells are their small area and their poor performance at elevated temperatures, i.e., re-radiation of wasted energy must be from relatively cool (70 F) surfaces. The small area restriction comes from problems of internal resistance and the necessity of working with single crystals; grain boundaries tend to disrupt the p-n junction. Moreover, small individual cells are more difficult to support and connect together. Some way of constructing a multi-crystalline, large-area converter would be a distinct advantage. There is report that this may have been accomplished by the Russians.

Better production techniques, however, may eventually allow thinner and lighter cells, and we may also be able to utilize the fact that cells are transparent to wavelengths longer than

the cutoff value. Nevertheless, the usefulness of solar batteries is at present limited to low-power applications, such as satellites.

For most applications, man will have to take along his source of energy in the form of either a chemical system or a nuclear device. As indicated in the table on page 25, a straight chemical reaction cannot exceed the order of 1700 watt-hours/lb. From the point of view of providing only electricity, the limit is the lower "free energy," which for a hydrogen-oxygen battery reaction amounts to about 1400 watt-hours/lb. The theoretical upper limits for most other battery types (silver-zinc systems, magnesium x m-dinitrobenzene, etc.) are less than this figure. Current hydrox fuel cells—battery-like devices in which one electrode acts chemically as if it were hydrogen, while the other one acts like oxygen—can deliver about 300 watt-hours/lb. Improvements may lead to 1000 watt-hours/lb; but, even at the limit of 1400 watt-hour/lb, it is clear that any electrochemical system will have a very short lifetime.

The future for chemical batteries lies in the field of energy storage for peak loads, dark periods in solar applications, and the like, rather than as prime sources. For example, a zinc-silver battery may deliver 700 watts/lb for periods of a minute or so. This probably exceeds the rating of even very high speed turbo-alternator units. Fuel cells may also have a future in space through solar decomposition of water to reverse the cycle. However, a space environment presents special challenges to battery systems, whatever their use. Chemical batteries are sensitive to ambient temperature and usually must be kept warm; in a zero-gravity environment they should be able to absorb any gases formed during charging (venting may lead to electrolyte loss); they must have low internal losses to minimize heat-rejection problems; and finally, operating in a zero-gravity environment, they must not impair performance through loss of natural convection in the electrolyte.

We must therefore turn to some sort of nuclear power for a prime source of energy. Isotopes show some possibilities, as indicated by the table on page 25. Phenomenal watt-hour/lb figures should be possible. For example, using polonium and thermocouples, one reported "atomic battery" could deliver about 800 watt-hours/lb over the isotope half-life. More efficient and lighter conversion might easily result in 10^4 to 10^6 electrical watt-hours/lb. Moreover, some isotopes present less of a radiation hazard than reactors; there is no critical mass requirement; and certain types of

"atomic batteries" are quite insensitive to ambient temperatures while yielding a high voltage per single cell. A battery of the latter type might operate on the direct conversion principle of collecting charged particles (protons or electrons emitted during the decay process) on a plate. The battery would require a vacuum in which to operate, which is readily available in space.

One fact about isotopes, however, is often overlooked: There will probably never be enough for any large-scale operation. For example, it is estimated that the total accumulated activity of Pm^{147} in the U.S. in 2000 A.D. will be 5 x 10^9 curies, or only about 2 megawatts of thermal decay energy. Similar statements could be made about artificially produced isotopes such as polonium. In fact, for this particular isotope, the backup power required in reactors per megawatt of decay power in polonium amounts to about 38 mw.

Furthermore, many isotopes, including polonium, are, if taken into the body, powerful poisons. This hazard is greatest, of course, when the isotope is fresh, and this corresponds with the launching event of a vehicle when the accident possibilities are highest. On the other hand, a nuclear reactor at startup has not yet generated many dangerous fission products and energy can be withdrawn at a controlled rate. These points, and particularly the first one, lead the author to question the use of isotope power supplies for other than very special purposes.

Turning now to fission reactors, a possible weight breakdown might be as follows: Reactor, 50 lb per megawatt of thermal power output; shield weight, 200 lb per megawatt of thermal power—assuming a crew dose rate of 5 rem/year, shadow shielding, a 2 ft diam spherical core and a separation distance of 200 ft. (Shield weight is approximately proportional to the square of the reactor radius.) This amounts to 250 lb/mw of power, compared with perhaps 10 lb per mw of jet power from a chemical rocket engine. And, of course, a nuclear rocket might involve a less compact reactor. Nevertheless, nuclear rockets should eventually be able to provide specific impulses beyond the reach of chemical rockets while maintaining comparable accelerations.

Convert Fusion to Electrical Energy

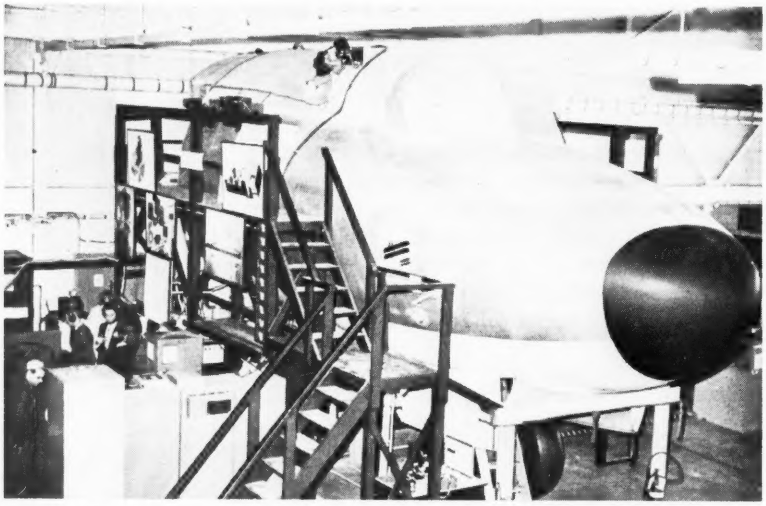
The energy of a fusion reactor will have to be converted to electrical energy if we wish to power communications equipment or use plasma or ion rockets. Conventional conversion equipment (turbo-alternator) and a radiator (even operating at 1200 F) will bring the performance down to around 8 tons per mw of electrical power output. This very heavy weight penalty limits electrical propulsion systems yielding specific impulses of the order of 10^4 to 10^6 sec to nearly infinitesimal accelerations—10^{-4} to 10^{-5} g's. To feed such electrical propulsion systems, we must have conversion equipment several orders of magnitude lighter than anything currently available. Furthermore, this equipment should preferably have no moving parts for high reliability and operate at high efficiencies and very high temperatures to minimize heat-rejection problems. Direct conversion devices currently available, such as thermocouples, cannot yet fulfill these goals.

Incidentally, corresponding to each energy source, there is a maximum specific impulse attainable when one correctly counts consumption of fuel and working fluid (jet material). A fission reactor burning 100 per cent of its fuel with 10 per cent conversion to useful jet power could give at the most specific impulse of 2.1 x 10^5 sec, corresponding to a jet velocity of 4.2 x 10^6 meters/sec. Photon rockets are sensible only if we can engineer complete annihilation of mass as an energy source.

Fusion and fission reactors offer some interesting magnetohydrodynamic energy-conversion possibilities, but it appears so far that these reactors may be large and bulky.

One can, however, conclude on a hopeful note. For short-duration power, chemical energy sources are adaptable to space vehicles. Solar batteries and isotope units can expand our capabilities under some circumstances, although we still have a very long way to go before we can supply large blocks of electrical energy without massive equipment. Moreover, our comparison here of thermocouples, silicon-cell solar batteries and conventional conversion equipment may be changed in the future.

Certain oxidic materials, such as ferrites and titanates, may exhibit desirable thermoelectric properties at temperatures as high as 600–1000 C. If such mechanical difficulties as joining techniques can be overcome at these high temperatures, ceramic units may deliver 10 per cent and higher efficiencies. And, of course, the overall weights of power systems will be quite favorably affected by the operation of these units at high temperature. Another omen of better things to come is the development of high-efficiency thermionic converters, which also operate at high temperatures.



Cabin for Space Men

This mock-up B-36 bomber housed five AF officers who successfully carried out a simulated five-day space flight recently. Movie and TV cameras atop dome checked their every movement; control panels (bottom left) were constantly watched during the experiment.

Synodic Satellites

(CONTINUED FROM PAGE 29)

velocity, completing one revolution in one lunar month. The only inertia forces to be accounted for, then, are the centrifugal forces apparently tending to pull each of the bodies away from the barycenter, balanced by the radially centripetal components of their mutual gravitational attraction.

It is therefore interesting to consider separately the equilibria of the radial and of the circumferential components of these forces.

The geometry of the general situation is illustrated on page 29 in which the moon-earth distance is assigned the value of unity, so that all other distances are expressed in nondimensional terms of fractions or multiples of it. It will be noted that in this nomenclature the relative distances of moon and earth from the barycenter complement each other to 1, and that their ratio λ/ϵ is equal to the mass ratio of earth to moon, which is about 81.3. The barycenter is located at a point about 73 per cent of the earth's radius from the earth center.

If we first consider the circumferential equilibrium, the sine components of the two Newtonian attractions must balance, there being no component of centrifugal force. Hence $\lambda(\sin\chi)/\eta^2 = \epsilon(\sin\psi)/\zeta^2$. One locus is, of course, the line of connection of moon and earth on which there are no transverse forces and the above equation is $0 = 0$ because the angles are zero or 180 deg.

However, for an asymmetric position, where this is not the case, the law of sines says that the numerators above are equal to ϵ/η and λ/ζ respectively, so that $\eta = \zeta$ is another solution which means that the bisecant of the earth-moon line is a locus for the eccentric positions of equilibrium.

The radial equilibrium of the forces (per unit mass) is expressed by equating the sum of the cosine components of the two attractions to the centrifugal force, viz.: $\lambda(\cos\chi)/\eta^2 + \epsilon(\cos\chi)/\zeta^2 = \rho$. Three more relations can be readily gleaned from the figure on page 29, namely for the cosines of the two angles occurring at the satellite and for the square of its radius vector. Inserting them in the above equation yields an equation between the two distances from earth and moon, η, and ζ, which contains powers up to the fifth:

$$\frac{2}{\epsilon}\eta^5\zeta^3 + \frac{2}{\lambda}\eta^3\zeta^5 - 2\eta^3\zeta^3 - \eta^5 - \zeta^5 -$$

$$\frac{1+\epsilon}{\lambda}\eta^3\zeta^2 - \frac{1+\lambda}{\epsilon}\eta^2\zeta^3 + \eta^3+\zeta^3 = 0$$

The locus of all points compatible with this equation is a curve whose main branch departs but little from the lunar orbit path except where it bulges out to loop around the moon, while another short loop swings inside from the moon center, as shown in the illustration on page 29.

The only places where the satellite could be in omnidirectional equilibrium, and hence capable of following

TOP HAND

...on a test stand

Absolute tight shut-off
reliability
safety • long life

Absolute shut-off dependability and safety is assured with ANNICO TEFSEAL SEATS, proven in severe fuel, chemical and gas services at pressures to 10,000 psi.

ANNIN... *most widely used remote shut-off valves for control of liquid propellants*

ANNIN's ten years of experience in the design and development of valves for rocket and missile ground installations has resulted in a new valve concept which has been *proven-in-service* for remote, manual and throttling applications. ANNIN's complete line is now available for pressures to 10,000 psi and temperatures from −400°F to 1600°F. Write for catalog 1500-C containing data on ANNIN valve bodies, operators and special design features.

ANNIN *Control* VALVES

THE ANNIN COMPANY
DIVISION OF THE ANNIN CORPORATION
6570 Telegraph Road, Los Angeles 22, California

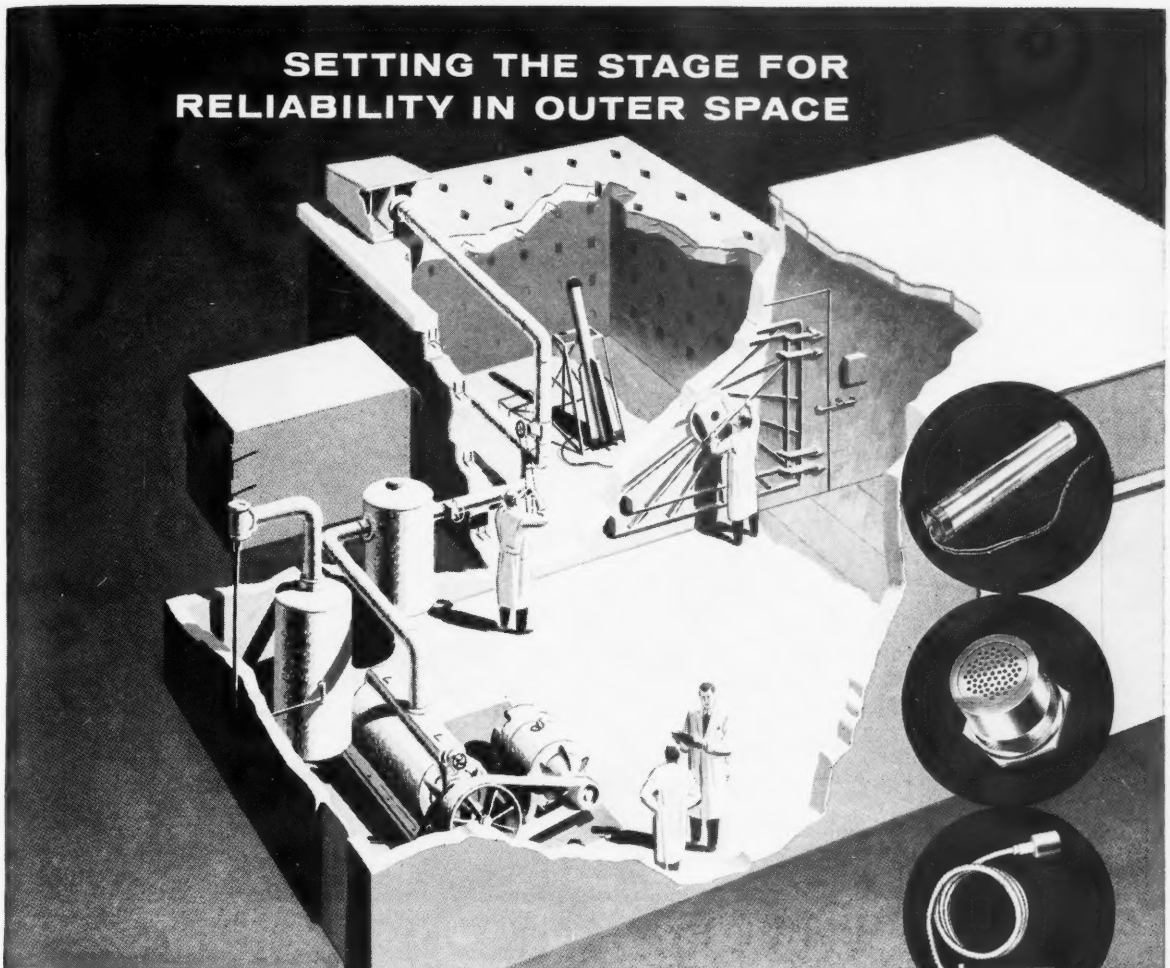
the constellation constantly, are those where both conditions are fulfilled, i.e., where the closed curves cross the dot-dashed axes on the illustration. These are the five Lagrangian points marked S_1, S_2, S_3, S_4, and S_5. Their astronomical constellation names, their computed coordinates as distances from earth (η), moon (ζ) and barycenter (ρ), all referred to unit moon-earth distance, and their bearing angle (θ) from the earth against the moon are listed in the table on page 29.

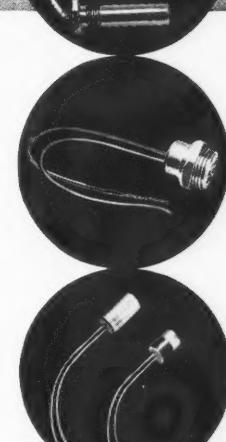
Some day it might also become of interest to navigate a space vehicle into a position where it can remain in a fixed constellation with respect to earth and sun. Again there will be—aside from perturbations—five equilibrium positions. Three of these, the sextiles and the opposition, would be two and six months, respectively, ahead or behind the earth in its annual orbit around the sun, practically at the same distance from sun as from the earth. The other two are the superior and inferior conjunctions, which are both located very close to 1 per cent of the sun's mean distance from the center of the earth—approximately 1.5 million km, assuming a mass ratio of earth to sun of 3 to 1 million.

In general, all five possible constellations are kinematically unstable. However, Routh has shown that the sextile is stable for mass ratios smaller than 1:25. In the conjunction constellations (the only ones where the Moon is close enough to exert a restoring influence which could be perceptible as a small periodic oscillation superimposed upon the selenoid orbit motion), the frequency of such oscillation is slightly slower than two per lunar month in the superior conjunction, and slightly faster than two in the inferior conjunction.

It is noteworthy that, in any of the libration constellations, the equilibrium is much less precarious in the circumferential than in the radial direction. In fact, anywhere in the arc of the locus of radial equilibrium between the sextile and opposition positions, the moon's influence is so weak that an error in bearing would create only a very slow departure from the initial constellation.

For instance, in a position of quadrature, i.e., at 90 deg from the moon, the peripheral pull component of the moon would be only of the order of a millionth of 1 g. Hence, it may be possible to counteract it for an appreciable period by the thrust of a very weak gas jet, after the manner of a satelloid. Similar thrust corrections may be considered to offset perturbations due to other astral bodies, notably the sun.





How **National Northern** assures dependability in high altitude performance of ignition devices, pyrotechnics, and explosive components.

As depicted here by the artist, National Northern technical experts prepare their high altitude test chamber built in cooperation with the U.S. Navy, for surveillance studies to determine how extremes of temperature and pressure affect the performance of explosive charges. Through exhaustive environmental tests like these, National Northern Division of American Potash & Chemical Corporation can assure you of "built-in reliability" for the vital performance of propellants for rockets and missiles, explosives, pyrotechnics, detonators, igniters, squibs, gas generators, fuses, and related items. Years of experience in research, development, and production of literally thousands of these components for leading defense and commercial customers is the reason why National Northern should be your first choice for a solution to your problems in the design and production of packaged pyrotechnic and explosive components. Write today for your copies of National Northern's current technical bulletins and facilities brochure—"Missile and Rocket Power Technology." Address National Northern Division, American Potash & Chemical Corporation, P. O. Box 175, West Hanover, Massachusetts.

NATIONAL NORTHERN DIVISION

TRONA American Potash & Chemical Corporation

West Hanover, Massachusetts

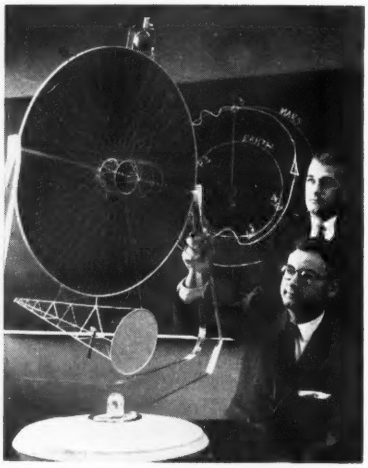
We invite inquiries leading to research and production contracts in the areas listed below.

Executive Office: 3000 WEST SIXTH STREET, LOS ANGELES 54, CALIFORNIA • 99 Park Avenue, New York 16, New York
LOS ANGELES, NEW YORK, CHICAGO, SAN FRANCISCO, PORTLAND, (ORE.), ATLANTA, COLUMBUS (O.), SHREVEPORT

National Northern's current fields of activity:

ROCKET-MOTOR-IGNITER DEVELOPMENT • GAS GENERATORS • SURVEILLANCE TESTING OF EXPLOSIVES AND AMMUNITION • EFFECT OF ALTITUDE ON PERFORMANCE OF EXPLOSIVES, PROPELLANTS, TRACERS AND INCENDIARY ELEMENTS • DESIGN OF ELECTRIC DETONATORS AND SQUIBS • AIRCRAFT VULNERABILITY TESTS AND EVALUATION • EXPLOSIVES METAL FORMING • BORON PELLETS

Boeing's Mars Probe



Boeing engineers Henry Hebeler (sitting) and Richard White look at $^1/_{20}$-scale model representing their advanced engineering study of unmanned Mars probe.

Scouting Venus or Mars with an unmanned space vehicle may prove the most practical and immediately informative space venture once manned satellites orbit the earth. Boeing recently showed this $^1/_{20}$-scale model of an unmanned Mars probe, which would be assembled on and launched from a satellite.

The disk-shaped vehicle, some 40 ft wide but weighing only 600 lb in full scale, would be propelled by an ion engine and would have its moving parts powered by solar batteries. It would be constructed largely of beryllium, steel wire and honeycomb sandwich, and would carry, among other instruments, a radio-noise scanner, cosmic ray and meteoroid counters, a radio altimeter and a tracking telescope with associated television and transmitting equipment.

Off for a three-year trip, the vehicle, guided by a programmed electronic "memory" taking corrections from an optical star-tracking system, would follow an Earth-Mars transfer orbit, circle Mars at an altitude of about 9000 miles, and then return to earth through another transfer orbit.

Boeing views the vehicle as an example of a rational engineering approach to advanced thinking on space ships, and does not intend to construct a full-scale vehicle now.

Space Technology Series To Be Offered by ARS-IRE

A series of six lectures on space technology to be given by prominent scientists in the field will be presented on successive Thursdays, 7:30 p.m., beginning Oct. 16, at the Garden City High School, Garden City, N. Y., by the N. Y. section of ARS and the Long Island section of IRE.

Featured topics and speakers are: Oct. 16, "Why Space Research," Herbert York, ARPA Chief Scientist; Oct. 23, "Space Propulsion," Martin Summerfield, Prof. of Aeronautical Engineering, Princeton Univ., and Editor of Jet Propulsion; Oct. 30, "Space Communications and Propagation," Joseph Vogelman, Director of Communications Lab, Rome ADC; Nov. 6, "Physics of Upper Atmosphere," Homer E. Newell, NRL; Nov. 13, "Trajectories of Space Vehicles," Robert M. L. Baker, Senior Scientist, Aeronutronics; Nov. 20, "Space Guidance," Charles D. Bock, Chief, technical staff, Arma Div. of American Bosch Arma.

Fee for the series to ARS and IRE members is \$4; nonmembers, \$6.

People in the news

APPOINTMENTS

President Eisenhower has nominated **Lt. Gen. James H. Doolittle** (AF-Ret.), chairman of the AF Scientific Advisory Board; **Alan T. Waterman,** director of the National Science Foundation; **Detlev W. Bronk,** president of the National Academy of Sciences; and **William A. M. Burden,** former assistant secretary of commerce, to serve on the new nine-member NASA council.

Gen. Doolittle has also been made board chairman, effective Jan. 1, 1959, of Space Technology Labs, a division of Ramo-Wooldridge slated to become a separate corporation on that date. **Simon Ramo,** present president of STL, will shortly return to his previous position as executive vice-president of R-W, and will be succeeded by **Louis Dunn,** current executive vice-president and general manager of STL.

Chance Vought has set up a new Dyna-Soar weapons system section and appointed **E. V. Marshall,** former chief of advanced aircraft section of advanced weapons engineering, to direct activities as engineering weapon systems manager. **W. B. Briggs** and **J. H. Boucher** have been named weapons system project engineers in the section, while **M. L. Chandler** becomes programs administrator, Dyna-Soar R&D and **Marvin G. Starr,** chief, customer liaison. **James F. Reagan** has been appointed chief engineer, electronics, of the newly established Electronics Dept.

Reagan

Hayes

Warren B. Hayes has been elected vice-president, Pacific Semiconductors, and will continue to direct its Engineering, Manufacturing and Sales Dept.

Thiokol Chemical has announced the following appointments in the Rocket Engineering Dept. of its Longhorn Div.: **John H. Sims,** former chief product engineer, to chief engineer in charge of the Dept.; **John T. Kerr,** former project engineer, to chief product engineer, Projects Div.; **Raymond A. McElvogue,** former chief engineer, to propellant plant manager, Production Dept. and Production Planning Div. **H. C. Havron,** former production planning supervisor and chief, quality control, Propellant Plant, has been named chief of the new Quality Control Dept. **Harris D. Gilbert,** supervisor of contract negotiations, has been promoted to manager of contracts, Reaction Motors Div., and **Richard P. Frazee,** to director of sales and service.

Sims

Kerr

McElvogue

Havron

Jesse Y. Bowman has been named project manager for the AF Minuteman's guidance and control system, at North American Aviation's Autonetics Div., and **R. M. Osborn,** former chief of the components engineering section, Guidance Engineering Dept., becomes project engineer. **David L. Weeks,** former project engineer, flight control projects, is now project engineer, Autonetics' Dyna-Soar program.

Chester A. Hill has been elected vice-president-assistant treasurer, Aerojet-General while **Levering E. Taylor** has been named resident contracting officer, Los Angeles Air Procurement District. **R. L. Lobo** has been made resident field service representative in charge of Thor-Able operations under the cognizance of Aerojet at Douglas' Tulsa plant.

Howard M. McCoy has been named assistant to executive vice-president, Robert L. Earle, Marquardt Aircraft Co.

T. A. Wilson, will head Boeing's newly formed Advanced Project Proposal Team in the company's System Management Office. He will be assisted by **D. E. Graves** and **J. W. Nealon. Ben F. Werner** has been appointed manager, weapon system support management branch.

A. C. Ducati has been named vice-president, development engineering, Giannini Plasmadyne Corp.

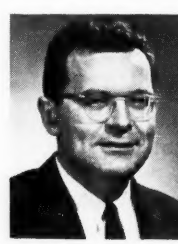
Walter R. Woodward, former chief engineer, Dynametrics Corp., has been upped to director of engineering.

Jonathan E. Boretz, former senior project engineer, Fairchild's Stratos Div., has been appointed principle engineer in charge of the development unit, Propulsion Section, at Martin Co.'s Denver Div.

Walter Krug has been appointed chief manufacturing engineer, Republic Aviation Corp.

Charles F. Robinson and **Leland G. Cole,** have been appointed chief research physicist and chemist, respectively, at Consolidated Electrodynamics Corp. **Clifford E. Berry,** assistant director of research, has been elected chairman of the Gordon Research Conference on Instrumentation for 1959.

Robert R. Miller and **Thomas V. Jones** have been appointed senior vice-presidents of Northrop Aviation. Miller was formerly corporate vice-president and general manager, Northrop Div., and Jones, corporate vice-president, development planning. **Richard R. Nolan** and **Irving Roth** have been elected corporate vice-presidents. Nolan also has been made general manager of the Northrop Div.



Halpin

Ryker

Gerald T. Halpin, Atlantic Research Corp., has been elected a vice-president, and will continue as manager of operations.

H. E. Ryker has been promoted to the new post of vice-president, operations, Ryan Aeronautical. He for-

merly was assistant to executive vice-president, G. C. Woodard.

William M. Lee, Pennsalt Chemicals has been appointed assistant to the vice-president and technical director, W. A. LaLande.

A. J. Toering, has been named manager of the new Defense Products Dept., Callery Chemical Co.

Toering

Bobrick

Frank Bobrick, has been appointed chief engineer at Wells Industries Corp.

Rear Adm. Earl E. Stone (USN-Ret.), former superintendent, Naval Postgraduate School, Monterey, Calif., becomes a director of Holex Inc.

John A. Rhoads has joined Packard-Bell Electronics Corp. as director of engineering, Technical Products Div.

In a realignment of executive personnel at Minneapolis-Honeywell Regulator's Industrial Products Group, **George M. Muschamp** becomes group vice-president, engineering; **O. B. Wilson,** vice-president, marketing; and **John M. Wilson,** director, engineering.

John F. Murray, has been appointed chief product engineer, Pesco Products and Wooster Div. of Borg-Warner. **Anthony Kreslik** has been named rotating equipment project engineer for Pesco Western Branch.

William J. Pietenpol has been appointed vice-president and general manager of Sylvania's Semiconductor Div. **Jerome R. Steen,** former manager of the division, becomes engineering reliability specialist for the Ballistic Missile Early Warning System Program of Sylvania Electronic Systems, while **Robert F. Schulz,** becomes manager, Reconnaissance Systems Lab, succeeding Walter Serniuk, who has been made manager of the division's Amherst Engineering Lab. **Gerald C. Rich** replaces Schulz as manager of projects engineering.

Wallace E. Rianda, has been made vice-president and general manager of Epsco's new West Coast division, Epsco-West. **William F. Gunning** has been named technical director, and **Ralph McCurdy,** to head production.

D. C. Duncan, former general manager, Beckman Instruments, Helipot Div., has been appointed director of contract sales for the company.

C. Burke Miles, former director of research, Westvaco Mineral Products Div., has been named assistant research director, Inorganic Chemicals R&D Dept., Food Machinery and Chemical Corp. **Robert L. McEwen,** former manager, Central Development Dept., becomes manager of development, and **Fred R. Sheldon,** general manager of the application section in the department.

Frank H. Erdman, has been named president, Kett Technical Center, Inc., R&D center of U. S. Industries, Inc.

Robert Erickson, president and director of Heath Co., has been named executive vice-president, Beckman Instruments. **William W. Wright** has joined the company as vice-president, finance.

Francis

Vitali

Harold E. Francis, former senior staff engineer, Chandler-Evans, has been named chief project engineer, and **Ercole J. Vitali,** former assistant chief engineer, has been made manager, Engineering Test and Experimental Depts.

Bruce L. Mims, former chief engineer, Barden Corp., has been elected vice-president of engineering.

Howard D. Weissman, has been appointed manager of contract procedures and analysis for the military operations at Allen B. DuMont Labs.

Kenneth P. Bowen, former vice-president, manufacturing and materiel, Northrop Aircraft, has joined The Sierracin Corp. as assistant to general manager C. Hart Miller.

Recently formed Systems Technology Inc. has appointed **D. T. McRuer and I. L. Ashkenas** as its president and vice-president, respectively.

Homer Austin has been appointed field engineer of the new Ft. Worth-Dallas Field Engineering Office of Whittaker Controls Div., Telecomputing Corp.

James S. Murray, former vice-president, Lindsay Chemical Div. of American Potash & Chemical, has been appointed director of the company's Washington, D. C. office, replacing **Herbert W. Yeagley,** who has been appointed director of defense programs. **Theodore A. Jonas** will assist Murray.

HONORS

John Francis Victory, has received NACA's highest award, its Distinguished Service Medal, for his contributions to aeronautics. Dr. Victory, whose civil service career spans almost half a century, was NACA's first employee.

Marvin Hobbs, consultant to Stewart-Warner Electronics, received a distinguished service award from Indiana's Tri-State College and its alumni association for his contributions to the defense effort.

Erwin Loewy, director of Baldwin-Lima-Hamilton Corp., has been awarded the AF Scroll of Appreciation for his role in convincing the government of the importance of extrusion press installations for the aircraft industry.

DEATHS

William Frederick Durand, pioneer in American aviation and a past president and honorary member of ASME, died Aug. 9 at the age of 99. He was born in Beacon Falls, Conn.; was graduated with honors from Annapolis in 1880, and, after leaving the service, received a Ph.D. from Lafayette College. Dr. Durand was an early and important contributor to hydrodynamic and aerodynamic science. Among many and diverse activities in a long and distinguished career, he was one of NACA's original 12 members and was chairman part of his 23 years as a member; the first American to deliver the Wilbur Wright lecture before the Royal Aeronautical Society of Great Britain; editor and contributor to a major work on the motion of gases, *Aerodynamic Theory;* president of ASME in 1924; and chairman of the Engineering Division of the National Research Council in the early years of WW II. Besides being elected an honorary member of ASME in 1934, he received the Guggenheim and John Fritz medals in 1935; the John J. Carty Gold Medal in 1944; and the ASME Medal in 1945. Dr. Durand was also the first recipient of the Wright Brothers Memorial Trophy, which is awarded by the National Aeronautical Association for "significant public service of enduring value to aviation in the United States."

In print

Spacepower, What It Means to You, by Donald Cox and Michael Stoiko, The John C. Winston Company, Philadelphia, 262 pp., illustrated by N. Stanilla. $4.50.

This is a book about rockets and space flight for general readers who want to know what is going on in this field—how it began, the present state of the art and where it is likely to take us. It is written in brisk, nontechnical style, and is well illustrated with striking color plates and black and white drawings.

The authors are both men of experience in the field, and know what they are talking about. Mr. Stoiko has been engaged in rocketry and aviation for more than 20 years, was associated with Project Hermes, participated in the White Sands Proving Grounds firing of Viking 11 and is co-author of a text on rocket propulsion. Dr. Cox was professor of education at the Univ. of Alabama, and for five years was educational adviser to the Commandant of the Air Command and Staff College in Montgomery, Ala. He is the author of numerous articles on space law, air power and aviation education.

—G.E.P.

Space Flight: Satellites, Spaceships, Space Stations, and Space Travel Explained, by Carsbie C. Adams, McGraw-Hill Book Co., New York, 373 pp., illustrated. $6.50.

Beginning with an admirable foreword by Wernher Von Braun, this well-written, brisk and informative book by the president of the National Research and Development Corp. ambitiously undertakes to survey the entire field of rocketry and space flight—past, present and future. And, considering the breadth of the job the author has undertaken to do, it comes out as a very high-level performance indeed. As they say of TV Westerns these days, this is an adult space book.

Mr. Adams begins with the history of astronautics, takes up the development and operation of the rocket, provides a useful summary of the theory of rocket propulsion, surveys satellites and space stations, space ships, space journeys, the architecture of the universe, human factors in space flight, communications in space, space navigation and even the possibilities and problems of interstellar flight. In a final paragraph, he undertakes to outline the position of man in his universe, and to explain the drive behind the space flight idea in terms of basic biological and psychological motives.

In so panoramic a work, a reviewer could readily point out some errors and omissions. Also, one or two chapters of the book contain some hard reading. But these are minor matters, and this volume is one in the growing popular and semi-popular literature of astronautics that is well worth owning. It is crammed with so many useful facts that, after the first pleasure of reading it entire has passed, it makes a most useful book to keep handy on the reference shelf. In addition to the well-chosen information in the text, there is a valuable bibliography at the end of each chapter for further reading and reference.

Mr. Adams for the most part devotes himself to reporting and explaining the ideas, philosophy and accomplishments of others, but does so in such a way as to give new insights into many older ideas and point out new uses and applications for many suggestions made by others.

One idea he does develop to a degree which makes it virtually his own deals with possible uses of the "Trojan points" in planetary orbits—those theoretically stable satellite positions fore and aft of a planet in its orbit, located at such distances that lines drawn through the centers of the satellite, planet and sun would form an equilaterial triangle.

If occupied by artificial satellites, these stable orbital positions, the existence of which is based on a hypothesis propounded about 1760 by Lecompte de Lagrange, could make communications throughout the solar system possible, Mr. Adams believes—even between planets in such parts of their respective orbits as to lie on opposite sides of the sun. Thus the Trojan points could be used, in the interplanetary traffic of the future, to "see around the corner" of the sun or any other body in the planetary system.

—G.E.P.

Magnetohydrodynamics

(CONTINUED FROM PAGE 20)

A coil imposes an additional magnetic field in the axial direction, which assists in obtaining uniformity of the initial gas breakdown and holds the ionized gas away from the coaxial cylinder walls during acceleration.

Consequently, a small amount of matter (the mass of the low-pressure gas) has been accelerated to a high velocity. This cycle is repeated, producing a rapidly pulsing jet of high-velocity gas.

Several designs of experimental pulsed electromagnetic accelerators, or "magnetic engines," have been constructed and tested at ARL. Gases used have included hydrogen and deuterium, and exhaust velocities as high as 500,000 mph have been obtained. This is equivalent to a specific impulse of approximately 23,000, about 100 times higher than the exhaust velocity of conventional chemically fueled rocket motors.

Because of the low thrust inherent in all known electrical propulsion systems, a motor of this type would not have application where high acceleration ($\sim {}^1/_2$ g, or greater) is required, as in takeoff from earth to a satellite orbit. In space, however, there are a number of possible applications where very small accelerations ($\sim {}^1/_{100}$–${}^1/_{10,000}$ g) applied over a long period of time are satisfactory.

For example, at low satellite orbits, in the neighborhood of 100 to 110 miles, only a small amount of thrust is necessary to offset the residual atmospheric drag and maintain a constant orbital altitude. Also, a low-thrust engine might be used to move from one orbital altitude to another or to change the shape of the orbit. By continuous application of thrust, even small acceleration gives rise to large changes in velocity over a period of time. Such an electric accelerator could also be used for propulsion of space vehicles from earth satellite orbits to the moon or planets.

So far, only the propulsion device itself has been discussed. In a practical system, a source of electrical power would be required. This could be supplied by a turboelectric generator utilizing a heat source of either a nuclear fission pile or a solar heated steam system. A solar battery, thermopile or thermionic emitters might also be used. In addition, a supply of working gas is necessary to provide the mass to be accelerated and ejected by the pulsating magnetic field. The gas might be hydrogen, ammonia, or lithium vapor.

The specific impulse produced by

the magnetic engine lies in the range between the best chemical rockets and an ion rocket system. In ion propulsion, metal vapors such as cesium are easily ionized by simple contact with hot tungsten and then accelerated by an electrostatic field to a high exhaust velocity.

The Avco designed magnetic engine and the ion rocket require a power supply of similar proportions. The main distinguishing feature of the magnetic engine, as compared with the ion rocket, is that the material is electrically neutral in the propulsion chamber and thus is not limited by so-called "space charge" considerations. From a design standpoint, the magnetic accelerator would have a much smaller size than the ion rocket. This fact is important in comparing overall powerplant weights of the two systems. In addition, the ARL magnetic accelerator can operate over a wider range of specific impulse ranging from chemical rockets to that of the ion rocket.

In our progress toward making manned space flight a reality, safe re-entry is a problem. A vehicle traveling at satellite velocity possesses tremendous kinetic energy and upon re-entry, much of this energy is converted into heat in the vehicle and in the air stream flowing around it.

For a manned re-entry vehicle to remain substantially intact while keeping its personnel and instrumentation unharmed, it is, of course, necessary for it to absorb as little heat as possible in slowing up in the atmosphere. It is possible that magnetohydrodynamics can make the task substantially easier by replacing a solid aerodynamic "wing" or drag surface with a magnetic field.

When a body traveling at or near satellite velocity re-enters the atmosphere, the gas around it is heated in the bow shock and ionized to a point where it becomes a relatively good conductor of electricity. In fact, on a weight basis, its conductivity may become considerably better than that of copper. Therefore the possibility arises that the motion of the gas may be influenced by a magnetic field, just as the motion of the copper wire is in a conventional electric motor or generator.

The primary advantage obtained by using these MHD forces is that this influence on the motion and, hence, a force between the body and gas, is obtained without the use of solid surfaces. Therefore the aerodynamic heat flow which such control surfaces would receive is reduced.

In this possible application of MHD to effect drag during re-entry, two important factors should be noted. First, an electromagnetic drag force is

effected. Second, the shock wave is displaced away from the vehicle, which may be expected to reduce heat transfer to the surface of the re-entry body. A third, and perhaps minor factor, is the generation of a large amount of electric current during this process which could be tapped for high-powered communication or other use in re-entry.

To make a precise evaluation of the possibilities of magnetohydrodynamics in flight, it is necessary to develop methods for treating MHD flow problems. ARL has conducted experimental and theoretical work of a fundamental nature which has led to some understanding of simple flows which involve magnetic fields and conducting gas. The first of these was a study of a theoretical and experimental nature where the motion of the gas was restricted to one dimension. A quantitative comparison with experiments and theory was obtained and has been reported.

An analysis has been made of the motion of a gas in the vicinity of the nose of a re-entry body (the stagnation point) in the presence of a magnetic field normal to the surface. This problem would correspond to the flow of an ionized gas which is heated in passing through a bow shock in front of a vehicle traveling at very high speeds and the subsequent effect on this flow through the introduction of a magnetic field normal to the surface.

A theoretical treatment has been made of a two-dimensional problem of the flow of a conducting gas and its interaction with a magnetic field normal to the flow direction. Experimental work has been conducted at the Laboratory which will be reported shortly.

Some predictions as to potential flight regimes of re-entry devices utilizing MHD drag will be found on page 20. By "seeding" the air in front of a vehicle with a few per cent of an easily ionizable substance, such as sodium or potassium, MHD drag may be obtained to lower altitudes and velocities.

One concept of what an MHD reentry vehicle might look like is found on page 20. The spherical body represents the capsule containing a man, or crew. Trailing behind the capsule is a loop of metal tubing. At the start of re-entry a small current is applied to the loop by means of electric batteries. This causes a weak magnetic field to form around the loop. The high-velocity flow of the ionized gas particles behind the shock wave causes this arrangement to act like a self-excited generator, the current flowing in the loop increases, causing a correspondingly higher magnetic

field, more current, etc. The drag effect may be calculated from a complex relationship between the velocity of the vehicle, altitude, initial field strength of the magnetic field and gas conductivity.

Magnetohydrodynamics is also being examined carefully from the standpoint of electric power generation. The direct interaction of a conducting gas with a magnetic field has long been attractive in speculation about power generation systems. At present, there are two ways in which MHD may prove useful for large-scale power production. The one which has received most attention is a fusion reactor operating at a temperature range of several hundred million degrees

To Generate Electricity

A more immediate application of MHD, however, would be in a generator which would replace the boiler, steam turbine and the electric generator in a system utilizing combustion gases of conventional fuels. The fundamental advantage of an MHD system is that it does not involve hot moving parts. Since such items as turbine wheels and blades limit operating temperatures and efficiencies, an MHD system could not only operate at appreciably higher temperatures, but might be much easier to build and more readily adaptable to large power stations.

The temperature at which a thermally ionized gas will conduct electricity to function in an MHD generator appears to be somewhat less than the temperature permissible for long-term exposure of unstressed ceramic materials. If this proves true, "low-temperature" MHD has an important potential application in this area.

The great potential of the fusion reactor is well known. The major problem is the containment of gases at temperatures of hundreds of millions of degrees. A very real problem exists, not only in the exceptionally high degree of containment required to prevent prohibitive cooling of the gas by solid walls, but also to prevent vaporization of these walls. The only types of forces which seem feasible for the physical containment of gases at such temperatures are those arising from the interaction of the high-temperature gas with magnetic fields.

An ionized particle moving in a magnetic field experiences a force directed toward a magnetic field line about which it moves in a helical path. The radius of this helix is known as the "gyro radius." The gas conditions necessary to produce a fusion reaction are such that the mean free path of the gas particles is much longer than the gyro radius for these particles in a magnetic field, if the magnetic field is strong enough to contain the gas. These conditions introduce a new region in gas physics where the dominating feature of the gas properties is no longer dependent upon collisions, as is the case in conventional gas dynamics.

In a typical design of a fusion reactor, an ion would have to move along a path hundreds or even thousands of miles long through the gas before it could be allowed to strike solid materials. Since 1956, a research program in this field has been carried out at ARL designed primarily to obtain temperatures of several million degrees K and to contain such gases at these temperatures.

Most of the ARL work dealing with gases at extremely high temperatures has been directed toward understanding the interaction of a gas and a magnetic field where the gyro radius is small compared to the mean free path in a magnetic field. Initial experiments were done with an electrodeless gas accelerator. Velocities corresponding to several hundred thousand degrees K were obtained and helped verify some basic ideas on the interaction of high-temperature gases with magnetic fields.

On the basis of the experience gained in these experiments, a second device was constructed at ARL, similar to the propulsion unit for space flight described above. Temperatures of the order of 1,000,000 K have been achieved with this device, shown on page 20.

Dress Rehearsal for Project Eclipse

Four Nike-ASP sounding rockets with 50-lb payloads launched in July from San Nicolas Island, in preparation for solar radiation studies to be made with them in the South Pacific (Danger Island) during total eclipse of the sun Oct. 12, set altitude records for two-stage solid propellant rockets by reaching 140–150 miles.

Methylamines, Perchloryl Fluoride in Production

Pennsalt Chemicals and Commercial Products both have new plants producing ton quantities of methylamines, and Pennsalt announced commercial availability of ton quantities of perchloryl fluoride. Both can be used as propellants.

Solids Boost Liquids

(CONTINUED FROM PAGE 31)

erosion or hot spots.

Low-temperature combustion products tend to be extremely fuel-rich and to contain solid matter, which returns us to the problem of gas-liquid interaction and the possibility of solids clogging injectors or acting as ignition nuclei in the tanks. Again, a solid propellant giving neutral gases with little solid residue would reduce these effects.

Composition and temperature of combustion products, then, in part affect the choice of solid propellant. The sensitivity of the propellant to initial temperature and the pressure of the rocket motor system during operation also affects this choice.

Most current rocket motors for military use must function with as little variation possible over the initial-temperature range −65 to 165 F. Some must function at an initial temperature as high as 200 F. Ambient temperature over this range influences burning rate of the solid propellant, density of the liquid propellants, injector discharge coefficient, amount of heat lost from the pressurizing gas, and degree of interaction between gas and liquid. These in turn affect thrust. All but burning rate and liquid propellant density are best evaluated by testing an actual motor system. The effect of burning rate and liquid propellant density can be studied analytically.

A small variation of burning rate helps compensate for the change in liquid propellant density with initial temperature. Some specific solid propellant in any group under study will consequently show an initial temperature sensitivity leading to least thrust variation in a proposed motor. This propellant can be found by substituting expressions for propellant burning rate in terms of pressure at the extreme ambient temperatures into the characteristic equations defining flow and pressure at various points in the rocket system. Equilibrium conditions at these extreme temperatures can then be compared with design conditions (usually at 70 F) to reveal the propellant introducing least thrust variation over the whole temperature range.

Finally, solid propellants insensitive to pressure during burning, or with a burning rate that slows with a rise in pressure, stabilize this kind of rocket motor system. These propellants, by not responding or by, so to speak, working against the system pressure, tend to damp pressure perturbations that might occur in the liquid propellant tanks and to burn stably when changes in pressure do occur. A pressure-insensitive solid propellant also raises tolerance to variation in injector-orifice and nozzle-throat areas.

A general picture of the dynamics of a proposed system can be seen in an expression for mass flow rate of gas from the generator. The theoretical mass gas flow rate needed to pressurize the liquid propellant tanks may be expressed as follows if we assume steady-state equilibrium and communication between the fuel and oxidizer tanks. Although the precise mathematical relationship would have to be modified to account for temperature and pressure during motor operation, this amplified expression can be played upon to show the utility of a particular gas generator design.

Solid propellants with neutral or slightly oxidizer-rich combustion products would promote wider use of gas generators. Until these become available, the engineer can adapt a present propellant to a particular liquid propellant system by adding some com-

$$\begin{array}{l} \text{Theoretical mass} \\ \text{gas flow rate} \\ \text{(steady state)} \end{array} = \frac{\text{Tank pressure} \left\{ \begin{array}{l} \text{Volumetric} \\ \text{flow rate,} \\ \text{oxidizer} \end{array} + \begin{array}{l} \text{Volumetric} \\ \text{flow rate,} \\ \text{fuel} \end{array} \right\}}{\text{Universal gas constant } (T/M)}$$

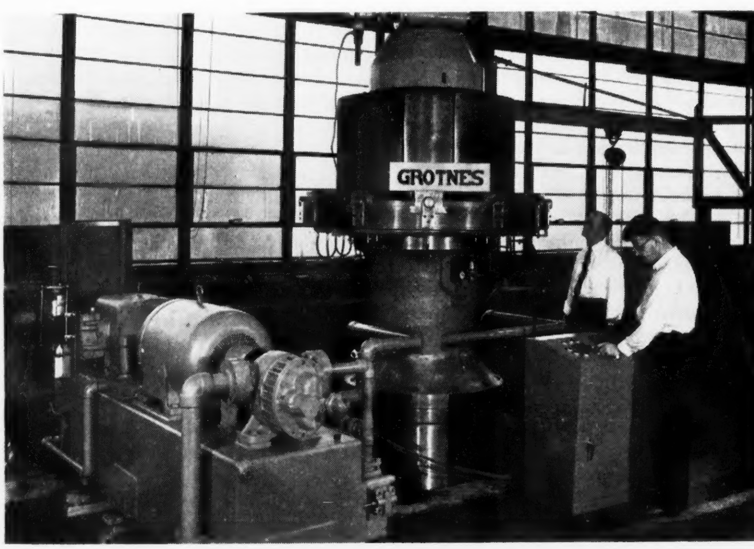
The ratio, T/M, represents the temperature of the pressuring gas, divided by its molecular weight. The equation shows that mass gas flow rate is inversely proportional to this ratio—that is, the lower the average molecular weight of a propellant and the higher the temperature of its combustion products, the less propellant is needed.

This expression can be amplified by experimentally measured efficiency coefficients to give an expression for mass gas flow rate in a particular liquid propellant motor. Against a background study of the possible gas-liquid reaction, the temperature limits imposed by the material structure of the motor system, and the effects of initial

plexity in the form of regulating devices.

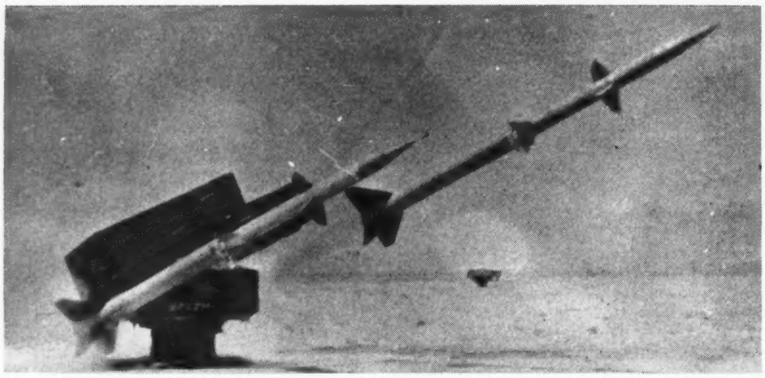
For example, solid propellant combustion products of too high a temperature can usually be cooled with a liquid (e.g., water or liquid ammonia) or solid diluent (e.g., oxalic acid) applied externally to the gas-generator charge. A gas-liquid reaction can be prevented by introducing a barrier between gas and liquid, for instance, a bag, a piston, or an insulating fluid topping. A valve will sometimes serve to vent the products of mild, nonreproducible gas-liquid reaction.

Based on a paper presented at the ARS 12th Annual Meeting in New York City Dec. 2–5, 1957.

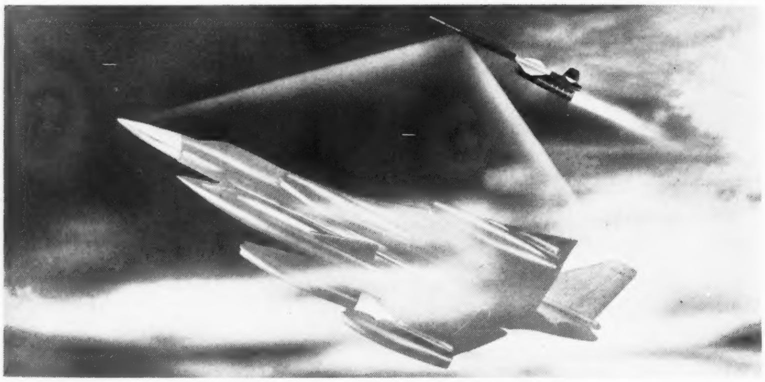


Expandering

Most powerful machine of its kind in the U.S., this expander (rating of 1580 tons), demonstrated recently by Grotnes Machine Works, Chicago, handles pieces weighing as much as $1^1/_2$ tons. It can stretch a 60 in. diam steel ring 2 in. thick and 26 in. high to 0.01 in. of a true circle. Such machines are the only means to give certain thin-walled missile structures necessary concentricity and roundness.



Talos takes off after "ghost" bomber simulated by Kingfisher.



Kingfisher Tested by Talos

The supersonic ramjet target drone developed by Lockheed Missile Systems Div. as the Q-5, and now being evaluated by the Army as Kingfisher, went through its first tactical flight against a groundbased Talos missile successfully, registering a hit on its kill detector. Kingfisher, which can fly above Mach 3 at high altitude, simulates the radar pattern of a bomber, and records either missile hits or miss angles and distances. After a test, it descends by parachute and impales itself on a nose spike for recovery and re-use. Articles in the June issue of ASTRONAUTICS describe the principles of this kind of drone, which will see wide service in testing the gamut of defense missiles.

Jupiter-C

(CONTINUED FROM PAGE 33)

when we discuss Jupiter-C's flight.

One of the nastiest problems that we encountered with Explorer was to make this proportional attitude control system linear under vacuum conditions. This was quite a trick, because, with a vacuum outside, you get supersonic nozzle flow even at very small rates of air flow. This tended to cause an S-shaped response curve, which the fellows in our mechanical lab found rather difficult to straighten out. But they succeeded, and it is now a very precise control system. There are four of these double-nozzle units attached to the instrument compartment—two for pitch and two for yaw. Roll-control signals feed to all four electromotors in the form of differential signals.

Finally, there is the now familiar tub, holding the second and third stages, and the fourth stage, Explorer I itself. The same type of solid rocket motor was employed in both clustered top stages and Explorer I, but the fourth-stage rocket motor had a slightly different propellant. The second stage consists of a ring of 11 motors, and the third stage of three motors nesting in this ring.

The tub is nothing but an aluminum can, having on its top and bottom matching sets of grooved bosses to support and guide lugs on the second-stage cluster. This lug-and-groove arrangement is in effect a zero-length support and guide lugs on the second-stage has traveled as little as half an inch within the tub, it is free and can make lateral moves of several inches without colliding with the tub wall. The same applies to third-stage clearance in relation to the second stage. The fourth stage, with the satellite payload attached to its front bulkhead, sits in a conical holder attached to the forward end of the third stage.

The tub rides on a conical "stool," which carries two heavy ball bearings to allow the tub to spin. Under the stool are two electric motors that drive the tub. Two sprocket rubber belts, not unlike those used in motorcycles, convey power from the motors to the tub.

The tub stages must be spin-tested for static and dynamic balance on a special rig consisting of a cage suspended on four rods inside a frame. In this testing, electric motors drive the tub, loaded with rocket motors, up to speed, and as spin starts any mass unbalances will cause the inner cage to vibrate within the outer frame. The amplitude and pattern of this vibration is measured stroboscopically to show where balance weights must be added. This technique is widely used in industry to balance dynamically things like gyros and flywheels. The spinup facility was designed and developed under an ABMA contract by Aerophysics Development Corp.

Upper-Stage Spin Rates

The spinning of the tub in actual flight is an interesting business. Prior to launching, we spin the tub to 550 rpm. About 70 sec after takeoff, a governor, controlled by a taped program inside the instrument compartment, gradually changes the regulator setting from 550 to 650 rpm. Again, at 115 sec after takeoff, it rises from 650 to 750 rpm. We use this seemingly complicated procedure to avoid resonance between the spin frequency of the high-speed stages and the bending frequency of the booster, which goes up as propellant is consumed in flight. At no time in flight, then, does Jupiter-C go through a critical frequency.

About 20 sec before propellant cutoff, the maximum spin rate of 750 rpm has been reached, and there is no change in the rate of spin during the free coasting climb to apex. Thus the high-speed stages are fired at 750 rpm. There is, however, one important consideration. The constant 750-rpm phase is also governor-controlled, which causes varying loads on the electric motors. These varying loads exert a reaction torque on the instrument compartment attached to the spin launcher, and in coasting flight this torque must be compensated by the compressed-air nozzles of the spatial-attitude control system. Otherwise, the instrument compartment could acquire a spin under the influence of this reaction, with resulting gimbal lock and spilling of the gyroscopes. The thrust of the air nozzles

has to be sufficient to cope with these "governor reaction torques." A lot of testing was done in this area before we knew our method was sound and safe.

The presence of the spinning cluster on the nose of the instrument compartment means that what we have to tilt, with the spatial-attitude control system, what is essentially a nonrotating body with a great big gyro mounted on its nose. As we tilt, we have to take into consideration the precession forces caused by this gyro. What we actually did was to put these unavoidable precession forces to good use. To tilt the unit in the pitch direction, we blew air out of the nozzles pointing in the yaw direction. Thus we used the precession force of the spinning cluster to tilt the unit in the pitch direction. All this was tried out on an analog simulator beforehand.

This picture would not be complete without following the Jupiter-C through its launching and flight stages.

Top photo on page 33 shows one of the last phases of preflight preparation. At the right, you can see the lox-loading line going into the Redstone booster, while the ladder at the left is used to connect the hydrogen peroxide line. In the so-called steam generator, hydrogen peroxide is catalytically decomposed to oxygen-rich steam, which drives the turbine. The turbine in turn drives the two centrifugal propellant pumps which feed the fuel and lox into the engine combustion chamber.

The launching table is an extremely simple thing—a steel table with four legs on which the missile rests prior to launching. The table top has a large hole through which the rocket jet passes. A conical deflector underneath spreads the jet out horizontally. All the equipment in the rear of the picture belongs to the service structure, which sits on two sets of wheels that run on wide-gauge rails. For the launching itself, the structure is rolled back about 300 ft from the missile.

The Countdown

With a new missile, where you have very little experience on how long it might take to go from one step in the firing preparations to the next one, one can almost state that "any similarity between X-time and real time is purely coincidental." It is one of the most important tasks of the experimental missile firing team to make X-time and real time gradually approach each other until, at the end of development you can hand your customer, whether miliarty or scientific, a realistic countdown table for your missile system. To play it safe, we provided an hour of padding in our countdown schedule for Jupiter-C. It so happened that the firing preparations for Explorer I proceeded so smoothly that at X −30 minutes, we had to call a synthetic one-hour halt in all operations to let real time catch up with the countdown!

The rocket takes off vertically, but by the end of the 155-sec burning time it has moved into a trajectory inclined 40 deg to the horizon. We did not apply a refined cutoff for the booster, but used instead the so-called depletion technique. That is, after about 149 sec of flight we energized a probe in each of the propellant discharge lines, and the first one to sense "no pressure" triggered a relay that closed both main valves to the propellant tanks. Cutoff occurred at 157 sec for Explorer I, which was 2 sec later than expected.

A timer sends current to the explosive bolts 5 sec after cutoff, this coasting interval being introduced to allow thrust to decay completely before the separating action. Otherwise, residual thrust, from propellants still in the lines, might supply enough thrust to run the booster into the nose

assembly if it were separated at the moment of thrust cutoff.

The spatial attitude control system then takes over to bring the separated stages horizontal with the earth's surface during the coasting period, which runs from cutoff at 157 sec to the time apex is reached at about 404 sec.

The same gyros that stabilize the rocket through the jet vanes of the booster up to cutoff control the system of compressed-air nozzles in the tail of the instrument compartment after separation. Thrust from these nozzles is made to tilt the separated section toward a horizontal plane substantially faster than the tilt of the trajectory itself approaches the horizontal. This is done to give the residual attitude errors time to decay and thus gain the highest possible accuracy in horizontal alignment.

The story isn't quite that simple, because our relatively crude cutoff technique made it impossible prior to launching to predict exactly when apex would be reached or to predict how horizontal travel would occur between takeoff point and apex. Because of the curvature of the earth, and because the separated hose assembly has to be exactly horizontal over the *local* horizon, it was necessary to introduce auxiliary tracking to furnish additional data during flight, for only by catching the moment of apex and accurately aligning the spinning tub was it possible to get the high-speed stages off in the right direction to obtain orbital flight.

To identify the instant of apex as accurately as possible, we used three independent methods. First, we tracked the missile by radar and used the radar plot to predict the instant and point in space of apex. Second, we had in Jupiter-C an accelerometer that, by means of telemetry, relayed to the ground the velocity buildup of the first stage. Cutoff velocity was fed into a simple computer on the ground which predicted the instant when apex would be reached. And, third, we used our standard Doppler-tracking network to furnish the same information.

These three independent apex predictions were cranked into a little manual calculator which enabled us to weigh their quality. For example, if one of the three predictions was based on readings of poor quality, it could be disregarded completely, or its weight in determining the average could be reduced to only 20 per cent of the others. In this fashion we predicted a rather reliable time of "average apex." This time for average apex was used to set a clock that triggered a radio signal, and this signal in turn caused the second stage to fire. All this, of course, had to be accomplished

during the 4 min or so available between first-stage cutoff and apex.

Now, to be quite correct, we did not want to fire the second stage exactly at the apex itself, but a little bit before. The second, third and fourth stages each had a burning time of about 5 to 6 sec, and there were several seconds between firing of one stage and burnout of the previous one. This meant that total elapsed time between firing of the second stage and end of burning of the fourth stage was about 24 sec. The firing of the second stage therefore had to take place at the right time prior to the predicted apex point. With this lead time, the vertical velocity component of the high-speed cluster would be exactly zero at cutoff of the fourth stage. Post-launching tracking data indicated that the angle of the fourth stage as it entered orbit was, in respect to the local horizon, as little as 0.81 deg off.

We think this was remarkable accuracy considering the many factors involved—drift of the gyros controlling attitude; the air-jet system directed by the gyros; timing of the apex transit; canting or unsymmetrical detachment of any stages; differences in ignition delay among rockets belonging to the same stage; and, last but not least, any unsymmetries or unbalances in burning or mass distribution of the three high-speed solid rocket stages, which were merely spin-stabilized.

Although total angular error at cutoff of the fourth stage was only 0.81 deg, it might interest you to know that Explorer I still would have orbited had this error been as high as 4 deg.

Based on a paper presented at the ARS-ASME Aviation Conference in Dallas, Tex.

Russian Eye on Space

(CONTINUED FROM PAGE 39)

has facilities for probing the ionosphere with vertically transmitted radio signals, for recording changes in the earth's magnetic field and for observing cosmic rays. The IGY has, of course, added impetus to the study and interrelation of these phenomena.

The Observatory devotes much attention to a study of the physical nature of stars, by means of a telescope fitted with two cameras with 40 cm lenses and photoelectric devices. Measurements have made it possible to establish a definite relationship between star spectra and luminosity. We have simultaneously photographed stars and their spectra in many portions of the sky, and are using this data for statistical studies of our own galaxy. Other galaxies have also come under spectral analysis, for we are studying their structure and chemical composition.

Although we do not as yet have really large telescopes, the Observatory will obtain in the near future a new reflecting telescope with a 260 cm diam mirror. We are now preparing electronic instruments for this telescope.

The Observatory is staffed by experienced scientists, such as A. Severny, V. Nikonov, E. Mustel and S. Pikelner, as well as by many young workers, not exclusively Russian, who are just beginning their scientific activities.

Congressional Resolution Bans Military Space Use

Both houses of Congress recently approved a resolution banning the use of outer space for military purposes. The resolution had put Congress on record as believing that "the nations of the world should join in the establishment of plans for the peaceful exploration of outer space, should ban the use of outer space for military aggrandizement, and should endeavor to broaden man's knowledge of space with the purposes of advancing the good of all mankind."

Government contract awards

Reaction Motors to Produce Packaged Liquid Rocket Engine

The Navy awarded Reaction Motors Div. of Thiokol a prime contract for production of a packaged liquid rocket engine (Guardian), which has been under development at RM with both government and company funds. This engine, an integrated system of propellent tanks, combustion chamber and other components, can be factory-loaded with propellants and stored ready for use at high and low temperatures for extended periods. RM expects that Guardian will be the first of a series of similar motors of various thrust, size, and burning time. The contract announcement culminates a decade of Navy planning for such a propulsion unit.

New Research Labs for School of Aviation Medicine

A bill authorizing $12 million for new research labs for the School of Aviation at Brooks AF Base passed Congress and is expected to be signed by the President. This money would add seven buildings to the seven now going up at Brooks at a cost of $9 million. The School of Aviation Medicine, now at Randolph AF Base, will move to Brooks in mid-1959.

Ford Instrument to Develop Inertial Guidance System

Ford Instrument Co., a division of Sperry Rand, will design and develop a "No-gimbal pure integration inertial guidance system" under AF contract for WADC's Weapons Guidance Lab. Ford began work on a platformless inertial system in the early 1950's, when it applied for 15 basic patents, 13 of which now await final approval, but at that time found analog computer work not advanced sufficiently to allow an airborn system. The new guidance should find wide application in aircraft, missiles and space vehicles.

AAM Universal Test System

Navy Bureau of Aeronautics has awarded the Allen B. Du Mont Labs a $386,000 contract to produce nine universal test systems (AN/DSM-32) for "Go-no go" checkout of guided missiles at depots and aboard ship.

Mace Equipment

Four Wheel Drive Co. received six new contracts totaling approximately $1.5 million—including a $400,000 subcontract from Goodyear Tire for Mace translauncher bogies and a $130,000 contract from Army Transportation Research and Engineering Command, Ft. Eustis, Va., for a number of 600-gal rolling fluid-transporters.

Bomarc Telemetry

Boeing has awarded Tele-Dynamics Inc. a contract to design, develop and manufacture a PDM-FM/FM telemetry system for operational flight testing of Bomarc.

Bendix to Supply Computer

Bendix Aviation Corp.'s Computer Div. was awarded a $300,000 contract for an electronic computing unit to be part of the missile-impact prediction system at Cooke AF Base, Calif.

Radar Navigator

Sylvania Electric Products Inc. received a $3 million plus AF contract for production of all-weather AN/APN-81 radar-navigation systems.

SYNOPSIS OF AWARDS

The following synopsis of government contract awards lists formerly advertised and negotiated unclassified contracts in excess of $25,000 for each Air Force, Army and Navy contracting office:

AIR FORCE

AFCRC, ARDC, USAF, Laurence G. Hanscom Field, Bedford, Mass.
Research directed toward application of photographic plates of artificial earth satellites for geodetic purposes, $45,000, **Georgetown College**, Washington, D. C.

Research directed toward experimental determinations of ionospheric characteristics using satellite radio transmission, $74,000, **Weston College,** Weston, Mass.

Theoretical and experimental research in thermoelectricity, $150,000, **MIT**, Cambridge, Mass.

Research directed toward experimental determinations of ionospheric characteristics using satellite radio transmission, $75,-000, **Univ. of New Hampshire,** Durham, N. H.

Commander Hq AMC, Wright-Patterson AFB, Ohio.
Design, development, fabrication and testing of high-performance inertial navigator, the Hipernas II, and applicable spare parts, technical reports and engineering data. End use is Army surveillance drone program, and AF satellite launch and space vehicle programs, $500,-000, **Avionics Div.,** Bell Aircraft Corp., P.O. Box 1, Buffalo 5, N.Y.

Experimental hydrocarbon fuels to be used in full-scale and engine tests, small scale burner rigs, thermal stability rigs, and in other chemical and physical tests to determine the suitability of the fuels for supersonic aircraft, $154,936, **Applied Science Labs., Inc.,** 140 N. Barnard St., State College, Pa.

Aerial target drones, $6,704,072, **Radioplane,** Northrop Aircraft, Inc., 8000 Woodley Ave., Van Nuys, Calif.

Conduct high performance X-10 drone flights to demonstrate weapon capability of the IM-99 Bomarc, $500,000, **North American Aviation,** Missile Development Div., Downey, Calif.

Hq AF Office of Scientific Research, ARDC, Washington 25, D.C.
Continuation of research on three-dimensional supersonic and hypersonic flow problems, $90,000 **Polytechnic Inst. of Brooklyn,** 99 Livingston St., Brooklyn 1, N.Y.

Research on radiation effects in solids, $55,600, **Brown Univ.,** Providence 12, R.I.

Continuation of research on microwave magnetic spectroscopy of free atoms and free radicals, $25,725, **Univ. of Maryland,** College Park, Md.

Continuation of study of nuclear structure and interactions, $41,924, **Purdue Research Fdn.,** Lafayette, Ind.

Research on high velocity impact studies, $102,192, **Univ. of Utah,** Salt Lake City 1, Utah.

Continuation of research in solid state theory, $62,750, **Univ. of Maryland,** College Park, Md.

Continuation of research on hypersonic flow by means of the shock tunnel, $124,-876, **Cornell Aeroanutical Lab,** 4445 Genesee St., Buffalo 21, N.Y.

Continuation of research on theoretical and experimental studies of mass transfer cooling, $116,859, **Univ. of Minnesota,** Minneapolis, Minn.

Continuation of research on nuclear emulsion studies, $50,624, **Univ. of Miami,** Coral Gables 46, Fla.

Continuation of research on nuclear interactions of 25–75 Mev photons, $38,777, **Univ. of Virginia,** Charlottesville, Va.

Research on high-speed gas dynamics,

$51,036, **New York Univ.**, New York 3, N.Y.

Photonuclear reaction studies, $32,000, **Univ. of Pennsylvania**, Philadelphia 4, Pa.

Ogden Air Materiel Area, USAF, Hill AFB, Utah.
Igniter M-41 for rocket motor M-58 solid propellant, $26,840, **Thiokol Chemical Corp.**, Elkton, Md.

ARMY

Boston Ordnance Dist., Army Base, Boston 10, Mass.
Satellite tracking program, $225,637, **Smithsonian Institute**, Washington, D.C.

Repair parts for Hawk missile, $745,624, **Raytheon Mfg. Co.**, Willow St., Waltham, Mass.

New York Ordnance Dist., 770 Broadway, New York 3, N.Y.
Starting mixture, guided missile, unsymmetrical dimethylhydrazine, $64,080, **Pioneer Chemical Co., Inc.**, 36–41 Vernon Blvd., Long Island City 1, N.Y.

Philadelphia Ordnance Dist., 128 N. Broad St., Philadelphia 2, Pa.
Nike spare parts and components, $1,557,487, **Western Electric Co.**, 120 Broadway, New York 5, N.Y.

Nike spare parts and components, $1,200,047, **Douglas Aircraft**, Charlotte Ordnance Missile Plant, Charlotte, N.C.

Study of cosmic ray attitude sensing device, $53,000, **Univ. of Maryland**, College Park, Md.

Research study in the field of microwave and radio frequency spectroscopy, $32,438, **Duke Univ.**, Durham, N.C.

Study of telemetry data analysis technique, $51,983, **Applied Science Corp. of Princeton**, Box 44, Princeton, N.J.

Multipurpose missile system test equipment, $1,500,000, **RCA Service Co.**, RCA, Cherry Hill, Delaware Township, Camden 8, N.J.

Research on the vulnerability of aircraft missiles, $100,000, **Johns Hopkins Univ.**, 3506 Greenway, Baltimore 18, Md.

U. S. Army Ordnance Dist., Los Angeles, 55 S. Grand Ave., Pasadena, Calif.
Missile technical representative services, $1,908,954, **Douglas Aircraft**, 3000 Ocean Park Blvd., Santa Monica, Calif.

Rocket engines, $180,000, **North American Aviation**, 6633 Canoga Ave., Canoga Park, Calif.

Guided missile, surface to surface, $2,423,653, **Firestone Tire & Rubber**, 2525 Firestone Blvd., Los Angeles 54, Calif.

Launching area items, $113,225, **Douglas Aircraft**, 3000 Ocean Park Blvd., Santa Monica, Calif.

Blue streak and emergency repair parts for the Nike system, $168,036, **Douglas Aircraft**, 3000 Ocean Park Blvd., Santa Monica, Calif.

Nike-Hercules launching area items, $24,005,157, **Douglas Aircraft**, 3000 Ocean Park Blvd., Santa Monica, Calif.

Dart, rocket motors and igniters, $36,094, **Grand Central Rocket Corp.**, P.O. Box 111, Redlands, Calif.

U. S. Army Signal Supply Agency, 225 S. 18th St., Philadelphia, Pa.

Low speed drone systems, $9,069,071, **Radioplane**, A Div. of Northrop Aircraft Inc., Van Nuys, Calif.

Radiosonde, $69,000, **General Instrument Corp.**, Newark, N.J.

Study of plasma acceleration, $56,085, **Stevens Institute of Technology**, Hoboken, N.J.

Study leading to the establishment of improved cables and connectors for guided missile systems, $370,000, **RCA Service Co.**, Div. of RCA, Camden, N.J.

Research study concerning paramagnetic resonance in the solid state, $50,000, **New York Univ.**, New York, N.Y.

Additional study for 9 months of solid state two level high power masers, $99,800, **Stanford Univ.**, Stanford, Calif.

Additional research work on moon-relay transmission, $35,000, **Univ. of Illinois**, Urbana, Ill.

Shelter surveillance drone control, $34,184, **Service & Supply Co.**, Tucson, Ariz.

Research study and investigation for 6 months of the wind response characteristics and the estimated wind deviation of the Little John rocket, $47,372, **Radio Corp. of America**, Moorestown, N.J.

Space Flight U.S.A.

(CONTINUED FROM PAGE 38)

$350 million of facilities.

These funds should satisfy Glennan, who sees NASA functioning rather as did NACA. But Dryden has spoken for a broad space program for NASA. His words are worth quoting, even though they were delivered before his recent appointment. "The space programs we will be proposing soon for NASA accomplishment are three-fold . . .adequate research on space technology problems. . .development and use of unmanned vehicles capable of carrying the desired scientific data-gathering apparatus. . .development and orderly use of man-carrying vehicles in the exploration of our solar system."

Work Through Contracts

The working arrangement to fulfill this program would, as Dryden sees it, be contractual between NASA and teams of experts and laboratory and industrial groups already in existence. According to Dryden, "So long as the technical and production competence of the aircraft industry can keep up with the exploding (sic) needs of the national space program, the same reasons (cost, limit on professionally trained people, and time) that discourage construction of new laboratories and scientific teams to perform work that can be done by in-being research organizations will apply to spacecraft development and construction."

NASA will add some new facilities to its existing ones, but so would have NACA. As Dryden says, most of the activity NASA will add to the nation's space program will come as applied research conducted in its facilities and through subsidizing the services of groups with "special competence in specific areas." Dryden has said, "NASA will have to develop new space vehicles." It is hard to imagine just what NASA will develop that other agencies are not already hot on the trail of. Indeed, the fate of any NASA plan to develop space vehicles may reflect in the proposal to give our national space agency Vanguard, that is to say, the minimum-satellite program.

NASA appears a minor term in the U.S. equation for space flight. The big factors must then be DOD and enterprising, forward-looking industrial concerns with some major position in the missile and aircraft field now. There will be no penny ante players in the game of space. At stake are multibillion-dollar projects and, at least potentially, the social fabric of our country.

By and large, industry takes subscription from DOD in the development and manufacture of missiles, and for understandable reasons both technical and military. But space programs do not demand military planning or supervision.

That leaders in the industry see this shows in the formation of "space technology" and "astronautics" divisions in companies large and small and, more particularly, in the consolidations and so-called joint ventures sweeping the business world. One can mention the truly impressive array of companies allied to work on Dyna-Soar and the recent confederation of GM, Thiokol with its already diverse facilities, and Callery Chemical, as well as modern corporate giants like General Dynamics.

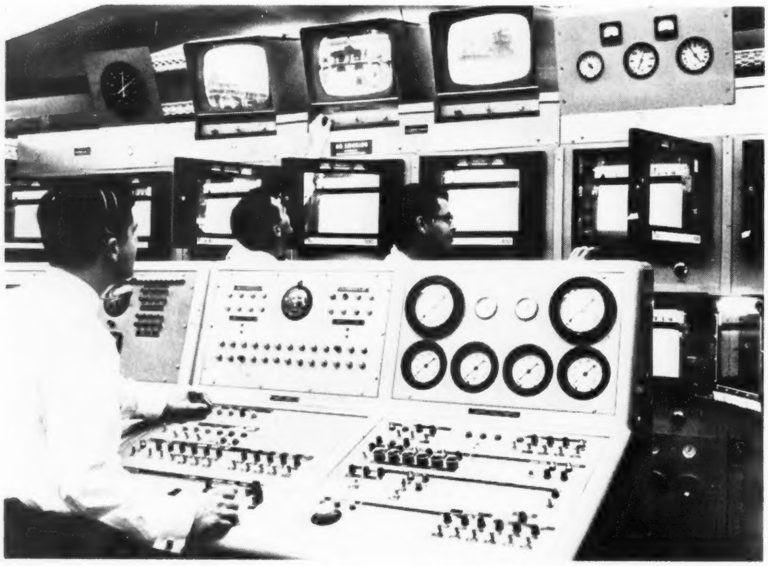
In conjunction companies can bid better, of course, for major missile programs. These will of necessity come through DOD. But in a few years, an industrial enterprise with central planning and management, varied engineering talent and facilities, and proven manufacturing resources will be in position to accept a franchise on space.

Marking Time

Where does this leave our space program? A fair answer might be, waiting for real planning and the events of the next three years. Large amounts of engineering talent will not be drained from the missile programs until 1962 has passed, in fear of military weakness in that period. When military hardware can be spared, or military aims coincide with possible space projects, as with the Sentinel (Pied Piper) satellite and the X-15, we may put some big hardware into space, and perhaps a man, though this is questionable. The major effort of space flight, as Mr. Glennan rightly observed, will be in the laboratory. Part of this applied research will take the form of developing engineering talent for space projects. The degree of preciseness in engineering will need to advance an order of magnitude, as they say, in the next few years to make space systems practical. Engineers across the country will be learning this need for precision and how to see it into hardware. Finally, the industrial community will reform to meet the challenges to its technological order, its social leadership, and its economic independence.

The leisurely formation of NASA and its retiring position signal this conservative entry to the age of space flight. There is only the danger of arriving in that age too little and too late.

—John Newbauer



TV Monitors Rocket Tests

Technicians in blockhouse view closed-circuit TV monitors (top), part of a $300,000 system of complete camera-receiver "chains" built by Hallamore Electronics to check static firings at Aerojet's Sacramento facility.

Peaceful Space Talk

(CONTINUED FROM PAGE 41)

aided in drawing up the program, and Soviet cooperation is expected.

The Russians presented only three papers at the meeting and again studiously avoided any reference to the vehicles or fuels used in launching their Sputniks, confining themselves, as usual, to geophysical data obtained by the satellites.

Dr. Sedov presented a paper on "Dynamic Effects on the Motions of Earth Satellites"; Dr. Ogorodnikov, a preliminary summary of "Optical Observations of Artificial Earth Satellites"; and V. I. Krassovsky, a paper on "Exploration of the Upper Atmosphere with the Help of Sputnik III."

Much of the material contained in these papers had previously been presented at earlier IGY meetings and the international astronomical conference held earlier in the month in Moscow, and attended by a number of the American delegates.

One item of interest in Dr. Krassovsky's paper was a description of the unusual "ion traps" used in Sputnik III to make direct measurements of the concentration of particles in the ionosphere, and thus determine ion distribution with height. Dr. Krassovsky also indicated that Sputnik III had passed through a relatively severe meteor shower in its orbital flight.

Fittingly held in a center of science—the Amsterdam Municipal University—the conference presented a number of outstanding technical papers, running the full gamut of the astronautical sciences, from propulsion to space medicine.

David Altman of Aeronutronic Systems presented an interesting paper on "Chemical Propulsion in the New Space Age." In the midst of a spate of papers on exotic propulsion systems, Dr. Altman plumped for chemical propellants, noting that chemical fuels would be used exclusively in long-range missiles and space vehicles in the immediate future (5-10 years) and that, even beyond that period, chemicals offer certain advantages over more exotic propulsion devices for both primary and auxiliary power systems.

Taking a similar tack in the first paper delivered at the Congress, Theodore von Kármán of AGARD, in the course of a discussion of magneto fluid dynamics in relation to space flight problems, pointed out that the most important task at present is not to dream up new and ingenious propulsion schemes, but rather to reduce the weight of devices which produce electric power.

Many of the discussions at the meeting centered on the intense band of radiation uncovered by the satellites. Russian papers made only passing reference to the radiation, but A. R. Hibbs of JPL presented a paper on the latest data obtained from the Explorers and Fred Singer of the University of Maryland offered a theory to account for the radiation and suggested ways and means of protecting against the radiation and of experimentally testing the theory.

Another outstanding American paper was that by W. E. Moeckel of NACA Lewis Lab on "Interplanetary Trajectories with Excess Energy," in which the author discussed reduction of the length of time required for interplanetary flight with the least excess energy. The paper reviewed calculations of the time components of such trips as a function of the velocity increments for several promising families of trajectories.

H. J. von Beckh of Holloman Air Development Center presented an interesting paper on weightlessness and its physiological and psychological effects on human beings, while Dr. Whipple discussed the feasibility of an orbiting astronomical telescope.

Exotic propulsion techniques came in for plenty of discussion at the meeting. Among the more important papers in this area were those by Dr. Sänger, on photon propulsion; by O. I. Rice of the University of North Carolina, on the recombination of atoms and other energy-exchange reactions; by Dr. Shepherd and J. H. Huth of Rand Corp. (see page 24) on electrical propulsion systems; by W. H. Bostich of Stevens Institute of Technology, on plasma motors; and by George C. Szego of G.E. on similitudes and limitations in unconventional propulsion systems.

Action on selection of a permanent secretariat and a permanent location for IAF headquarters was put off for a year because of lack of funds, but the problem will be studied in detail this year while efforts will be made to raise funds for this purpose.

The budget was increased to \$3000 for the coming year, \$1000 more than for this year, the increase coming from higher membership dues. The Congress voted to increase ARS dues from \$1000 to \$1500, BIS dues to \$500 and Russian dues to \$100. Minimum dues have been set at \$15 for societies with less than 100 members, rising at the rate of \$10 per additional 100 members.

Societies from Nationalist China, Bulgaria, Greece and Israel became IAF members at the Congress, while India, Czechoslovakia and Iran were given observer status. The Chilean society and the Univ. of Cuyo were dropped for nonpayment of dues and the Egyptian society placed on notice for the same reason.

For the first time, the International Telecommunications Union had an observer at the Conference. The IAF is working with the ITU to find a solution to radio frequency allocations for astronautical purposes, under the chairmanship of Andrew G. Haley.

A revised and expanded glossary is planned for the near future, and it is hoped that the new volume will be a complete handbook of rocketry and astronautics. In addition, a guide is being prepared for international decimal classification of astronautical literature.

Numerous social functions spiced the meeting program. A reception was held at the Rijksmuseum, among the Rembrandts and Vermeers the first evening; one day was left open for a trip to Rotterdam; the municipality of Amsterdam provided a free trip through the canals one evening; and the Congress came to an end with a gala banquet which drew an attendance of 200.

During the Conference, President Haley was honored with the Grotius Medal from the Grotius Foundation of the city of Munich for distinguished contribution to international law, along with Charles Rhyne, president of the American Bar Association.

Linking Computer-Machine Cuts Wing Production Time

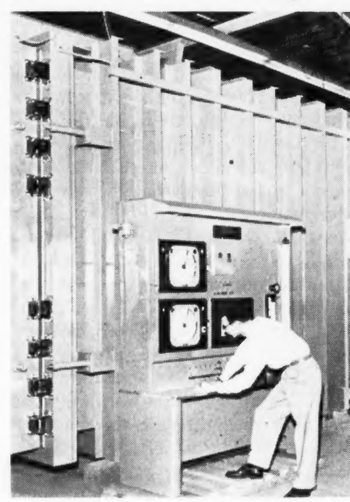
Convair has realized a long anticipated dream of going straight from equations to automatic machining of an aerodynamic surface by linking a digital computer, a numerical converter that puts machining directions on magnetic tape, and a tape-directed horizontal mill capable of cutting compound curves within the limitations of three axes.

This linking of computer and machine tool will cut the 2000 or so man-hours needed to make a wind tunnel model wing to 200 hours or less. Upper and lower surfaces of the knife-edge wing for the F-106 have been made in one unit by means of this technique, which suggests the extent to which it may be applied to missiles and supersonic aircraft.

Airborne Control for Lacrosse

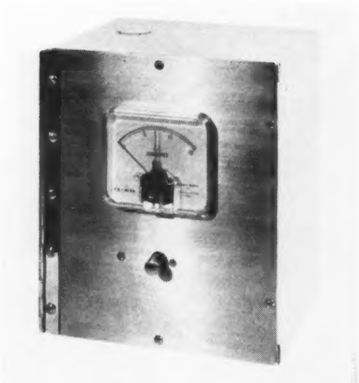
Cornell Aeronautical Laboratory is developing an airborne control system for the Army Lacrosse surface-to-surface missile. The present system is controlled by a forward observer on the battlefield.

Environmental Chamber For Vibration Testing



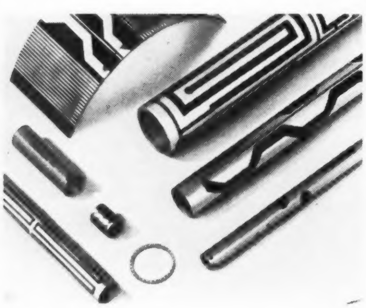
This 8 x 12 ft (inside) environmental chamber, built by Tenney Eng. Co. for Stromberg-Carlson, will hold a vibration testing machine weighing 3 tons, and give temperatures from −120 to 350 F, humidity from 20 to 95 per cent, and altitudinal pressures up to 20 mi. A 20-ton concrete block isolates the vibration machine. The facility will be used by Stromberg-Carlson to test military electronic equipment, including missile components.

New equipment and processes



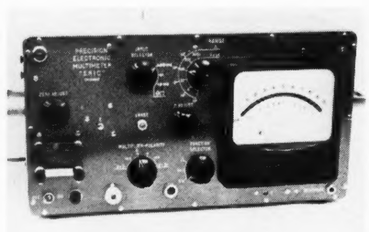
Safe-Load Relay: Designed to respond to all momentary overloads, relay adapts to machine tools and multimotored transfer and automation setups. Relay can be reset immediately as it cuts off current. Baker Perkins, Inc., Saginaw, Mich.

Perforated-Tape Reader: An input unit with Burroughs 220 electronic date-processing system, a commercially available tape reader operates at 1000 characters/sec. It photoelectrically reads paper-tape programming data into control and computer systems; adapts to any standard-width commercial tape, from five to eight-level code. Burroughs Corp., Electro-Data Div., 460 Sierra Madre Villa, Pasadena, Calif.

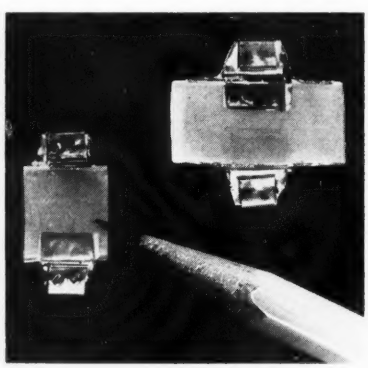


Tubular Circuits: Solderable silver circuits on either the exterior, interior or both surfaces of almost any nonconducting tubing. Generally, an inside diameter of 1/2 in. is required for circuitry, but continuous coatings for shielding or conduction have been applied to tubes with 0.020-in. diam. J. Frank Moston Co., Flourtown, Pa.

Phase-Lock Receivers: Series 1400, covers frequency ranges of 215 to 260 megacycles. Phase-lock increases data accuracy under weak signal conditions by lowering receiver threshold, improving the signal-to-noise ratio. In the case of IRIG FM/FM telemetry using standard receivers of 500-kc bandwidth, noise bandwidth can be reduced by a factor of approximately 2.5 when all subcarriers are used. News-Clarke Co., Div. of Vitro Corporation of America, 919 Jesup-Blair Drive, Silver Spring, Md.

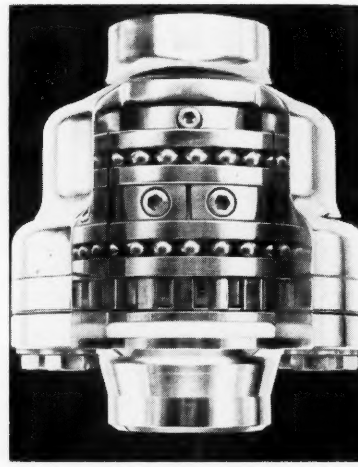


Universal Meter: Model REL-500, performs as a stability meter, millivoltmeter, micromicroammeter, megohmmeter, capacity meter, PH meter and as an electrostatic volmeter. Current is measured without adding appreciable resistance to circuit being measured. Full-scale reading, 0.001 μa; input impedance, up to 100 million megohms. Rheem Manufacturing Co., Electronics Div., 7777 Industry Ave., Rivera, Calif.

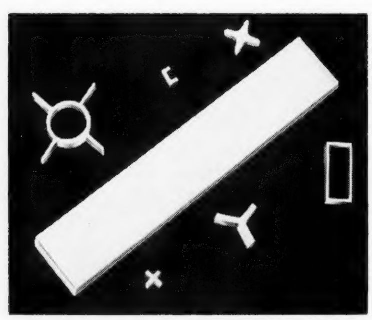


Glass Capacitors: Operating at temperatures up to 572 F with capacitances up to 10,000 mmfd, new capacitors give DC voltage of 300 V at peak working temperatures, are highly resistant to nuclear radiation. Corning Glass Works, Corning, N.Y.

Scintillation B/A Spectrometer: For automatic data processing with atomic instrumentation, including isotope purity analysis, isotope identification and analysis in single and multiple tracer studies, activation analysis, and investigations of physical interactions, absorption and particle scattering. Baird-Atomic, Inc., 33 University Road, Cambridge 38, Mass.

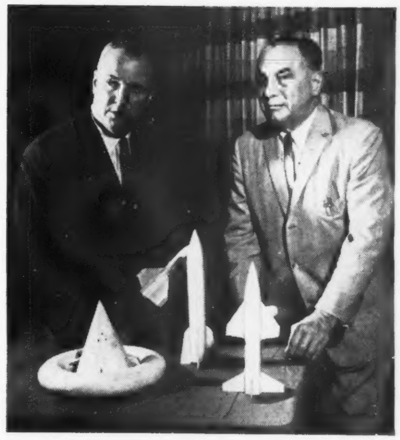


Cryogenic Swivel Joint: Lox and other liquefied gases in transfer can circulate freely in the thrust-bearing races of this swivel joint, taking advantage of the lubricity of the fluid. Joints under 2 in. diam handle pressure to 2500 psig at 160 F. Chiksan Co., Subsidiary of Food Machinery and Chemical Corp., 33 N. Pomona Avenue Brea, Calif.



Extruded Teflon: In a variety of intricate, dimensionally accurate, extruded shapes. Continuous shapes for electrical and electronic uses have a dielectric strength from 500 to 2000 v/mil; no change of electrical properties with temperature from −25 to 250 C or frequency from 60 cycles to 100 mc; and 3 zero moisture absorption. Pennsylvania Fluorocarbon Co., Inc., 1115 N. 38th Street, Philadelphia 4, Pa.

An invitation to senior scientists and engineers



A $14,000,000 R & D Center, housing 9 new laboratories, was revealed as core of Republic's $35,000,000 Research and Development Program at recent announcement by Mundy I. Peale, President, and Alexander Kartveli, Vice-President for Research and Development.

....To join Republic Aviation's new $35 million Research and Development Program for spacecraft, missiles and advanced aircraft

In announcing Republic's $35 million research and development program, designed to arrive at major breakthroughs in the aviation industry's transition to astronautics, Mundy I. Peale, President, set the following objectives:

> "...ACCELERATION OF PROJECTS ALREADY UNDER WAY AT REPUBLIC ON LUNAR PROGRAM FOR MANNED SPACE VEHICLES, AND MISSILES TO DESTROY ORBITING WEAPONS, AND INITIATION OF INVESTIGATIONS LEADING TO NEW CONCEPTS FOR INTERPLANETARY TRAVEL."
>
> "...RADICAL NEW FAMILIES OF LONG-RANGE AIR-TO-AIR MISSILES AND AIR-TO-SURFACE BALLISTIC MISSILES FOR STRATEGIC AND TACTICAL AIRCRAFT."
>
> "...VERTICAL TAKE-OFF FIGHTER-BOMBERS, HIGH-MACH FIGHTER-BOMBERS, AND SUPERSONIC TRANSPORTS."

Alexander Kartveli, Vice-President for Research and Development, emphasized that Republic's program "will not duplicate in any way investigatory work currently in progress elsewhere, but will stress novel concepts and new approaches to basic problems of missiles and space technology."

The program includes construction of a $14 million R & D center to house 9 new laboratories, and anticipates doubling the present research staff.

Senior men interested in the new possibilities created by a simultaneous exploration of all aspects of Flight Technology are invited to study the functions of the new laboratories for more detailed information:

SPACE ENVIRONMENTAL DEVELOPMENT LABORATORY
To simulate space flight conditions and test missile, satellite and spacecraft systems and components; investigate human engineering problems.

RE-ENTRY SIMULATION & AERODYNAMIC LABORATORY
To study hypersonic shock dynamics, real gas effects, heat transfer phenomena and magnetohydrodynamics.

MATERIALS DEVELOPMENT LABORATORY
Study effects of high velocity, temperature, and space environment on materials for spacecraft, missiles and advanced weapons.

GUIDANCE & CONTROL SYSTEM DEVELOPMENT LABORATORY
To develop and test guidance and control systems for spacecraft, missiles and aircraft.

ELECTRONICS DEVELOPMENT LABORATORY
Study and explore all problems connected with highly specialized, complex electronic systems required for advanced forms of spacecraft, missiles and aircraft.

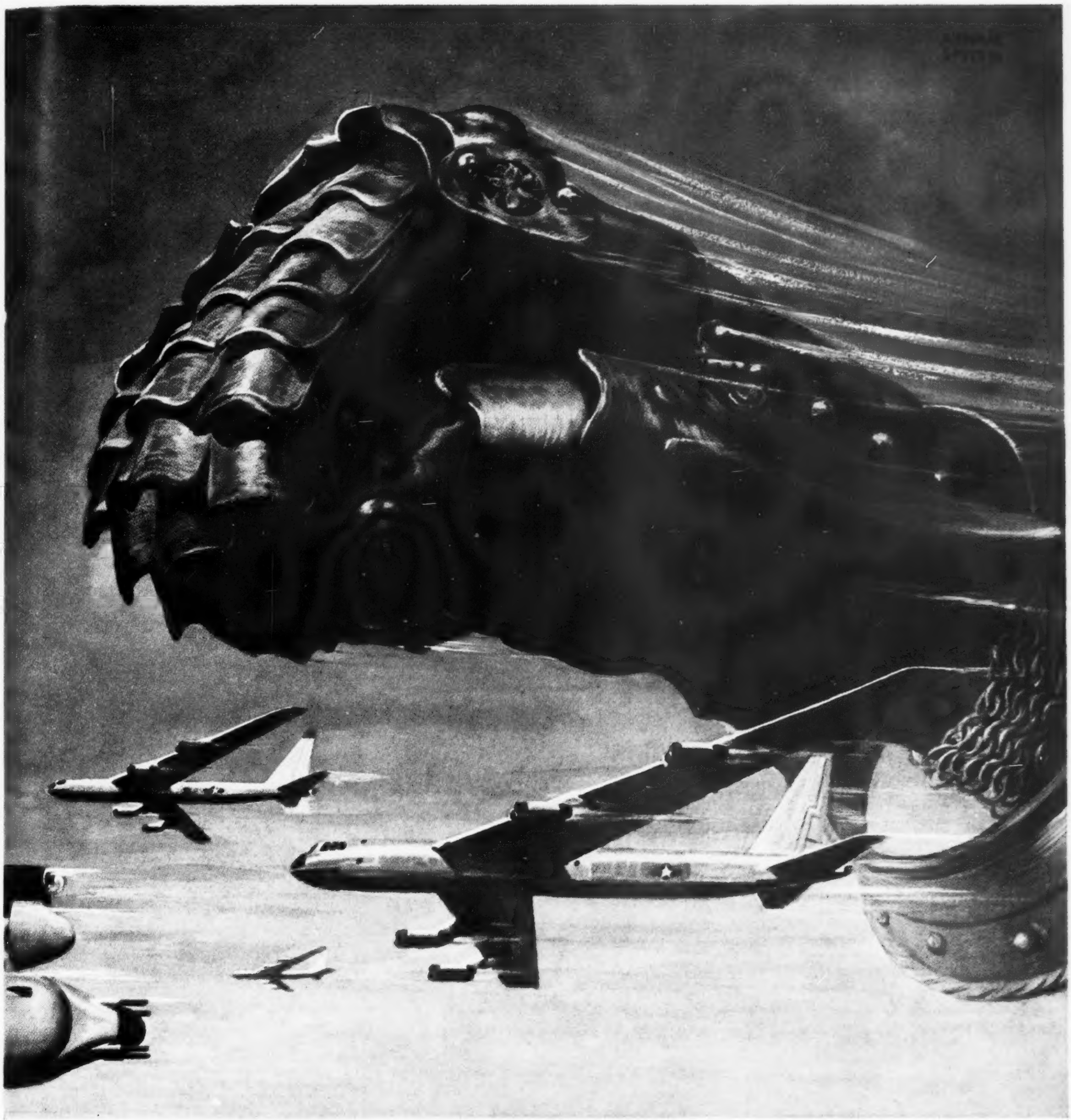
ADVANCED FLUID SYSTEMS DEVELOPMENT LABORATORY
To develop and test fluid power systems for spacecraft and missiles capable of operation under extremely high temperature, high pressure conditions.

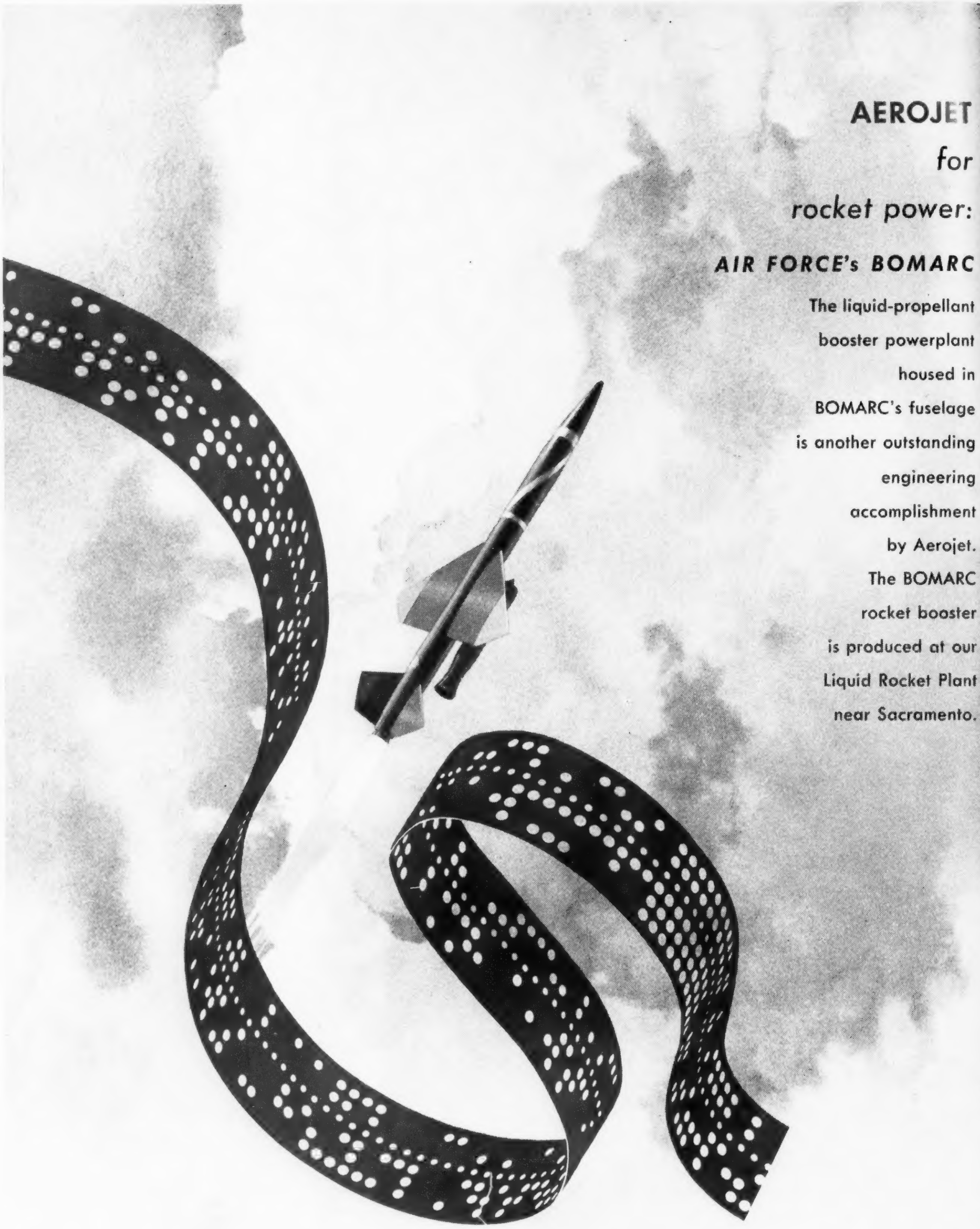
MANUFACTURING RESEARCH & DEVELOPMENT LABORATORIES
To develop advanced manufacturing processes and techniques for materials used in missiles and spacecraft. Laboratories for each of the following areas: *Non-Metallics, Metallics, Welding.*

Qualified men are invited to write directly to:
A. Kartveli, Vice President, Research and Development

REPUBLIC AVIATION
FARMINGDALE, LONG ISLAND, NEW YORK

Index To Advertisers





AEROJET for rocket power:

AIR FORCE's BOMARC

The liquid-propellant booster powerplant housed in BOMARC's fuselage is another outstanding engineering accomplishment by Aerojet. The BOMARC rocket booster is produced at our Liquid Rocket Plant near Sacramento.

AEROJET-GENERAL CORP.

THE GENERAL TIRE

A SUBSIDIARY OF THE GENERAL TIRE & RUBBER COMPANY

Engineers, scientists—investigate outstanding opportunities at Aerojet. (Plants at Azusa and near Sacramento, Calif.)

ET

or

r:

RC

ant
ant
in
ge
ng
ng
ent
et.
RC
er
ur
nt
o.

19